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DEVELOPMENT OF GUIDELINES FOR ENHANCEMENT OF THE GRID-ORIENTED PUBLIC SHELTER MODEL

FINAL REPORT

RTI/2083/00-05F

FEMA CONTRACT NO. EMW-C-0312

UNIT NO. 4211G

SEPTEMBER 1981

RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

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Over the last few years, FEMA (formerly DCPA) developed a computer program for analyzing scenarios about civil defense against a national nuclear attack. This model, names TENOS (Technique for Evaluation of National Operations Systems), can assess the expected damage under a variety of scenarios. This study was designed to collect available population and shelter data, to analyze that data, to examine appropriate methodologies for enhancement of the quality of estimates of both blast and radiation shelter spaces within grid

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cells, and to design specific algorithms to be used to create or improve these estimates. These shelter and population estimates are to be contained in a grid file which is used by TENOS. To achieve project objectives, RTI examined NSS and other data bases to assess the completeness of the shelter information used by the TENOS system, developed strategies to compensate for missing data required by the TENOS model, and developed both methodologies and algorithms to allocate the NSS shelter data to the 2' x 2' grid system. The algorithms described in this report reflect the best compromise between accuracy and efficiency based on RTI's understanding of the characteristics of TENOS and the problems addressed by it. Algorithms were developed in five areas; i.e., Code A mine spaces, risk area blast spaces, host area fallout spaces, home basement spaces, and a procedure to allocate spaces and population to grid centroids.

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DETACHABLE SUMMARY

DEVELOPMENT OF GUIDELINES FOR ENHANCEMENT OF THE GRID-ORIENTED PUBLIC SHELTER MODEL

BY

R. N. Hendry
R. O. Lyday
G. L. Bilbro
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FOR

Federal Emergency Management Agency
Washington, D.C. 20472

FEMA Review Notice

DETACHABLE SUMMARY

This final report is submitted to the Federal Emergency Management Agency (FEMA) in completion of FEMA Contract No. EMW-R-0312, entitled "Development of Guidelines for Enhancement of Grid-Oriented Public Shelter Model."

Over the last few years, FEMA (formerly DCPA) developed a computer program for analyzing scenarios about civil defense against a national nuclear attack. This model, named TENOS (Technique for Evaluation of National Operating Systems), can assess the expected damage under a variety of scenarios. The main source of data for TENOS are the National Shelter Survey (NSS) file which is ordered and grouped by standard location area and MEDList from the Bureau of the Census which is ordered by MCD or Block Group codes. Unfortunately these location codes do not correspond to the 2' x 2' grid area used by TENOS.

The effort described in this study was designed to collect available population and shelter data, to analyze that data, to examine appropriate methodologies for enhancement of the quality of estimates of both blast and radiation shelter spaces within grid cells, and to design specific algorithms to be used to create or improve these estimates. These shelter and population estimates are to be contained in a grid file which is used by TENOS.

To achieve project objectives, RTI examined NSS and other data bases to assess the completeness of the shelter information used by the TENOS system, developed strategies to compensate for missing data required by the TENOS model, and developed both methodologies and algorithms to allocate the NSS shelter data to the 2' x 2' grid system. RTI did not expend significant effort to integrate these algorithms into a system for preparing the grid file. Rather, the effort was expended in improving individual procedures or examining alternative ones.

The algorithms described in this report reflect the best compromise between accuracy and efficiency based on RTI's understanding of the characteristics of TENOS and the problems addressed by it. Algorithms were developed in five areas; i.e., Code A mine spaces, risk area blast spaces, host area fallout spaces, home basement spaces, and a procedure to allocate spaces and population to grid centroids.

The algorithm for estimating Code A mine spaces is an improvement over current methods, however, additional effort should be expended to develop better indicators of potential shelter. Other Code A shelter space estimates are considered adequate. Blast code and space estimates for risk areas using the algorithm recommended herein showed remarkably good correspondence for the sample selected. Additional samples should be taken to determine the reliability of these procedures and make any adjustment found to improve the estimation algorithm. Methods for estimating host area shelter is considered to represent a significant improvement over current methods. The home basement estimating algorithm is believed to be adequate, although the present procedure confines their use to the occupants of the homes. The most significant algorithm emerging from this effort is the allocation procedure based on relaxation methods. There is a real need to develop a clearly defined correspondence file which will enable an improved shelter location procedure for the NSS that is consistent with census locations especially for 1980 census data.

RTI recommends that some or all the algorithms developed be included in a set of computer code which will enable the preparation of an improved grid file for TENOS. Further work is recommended in a number of related areas.

SEPTEMBER 1981

FEMA CONTRACT NO. EMW-C-0312

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FEMA REVIEW NOTICE

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I. INTRODUCTION

This final report is submitted to the Federal Emergency Management Agency (FEMA) in completion of FEMA Contract No. EMW-R-0312, entitled "Development of Guidelines for Enhancement of Grid-Oriented Public Shelter Model."

In planning for crisis situations, the magnitude of the crisis must be estimated. If there are alternative crises, alternative responses (scenarios) and large geographical areas, and/or a large number of people involved (such as the total United States), then a computer based scenario driven simulation "model" must be used. Over the last few years, FEMA (formerly DCPA) developed a casualty assessment computer program for analyzing a variety of defense scenarios against a large-scale nuclear attack. This model, named TENOS (Technique for Evaluation of National Operating Systems), can assess rapidly the expected damage (fatalities, etc.) of an attack.

Any simulation requires that input data be supplied in a specified form. Inherent in TENOS is a gridding scheme that requires that the area (including shelter, population, and weapon effects) be defined by grids of two minutes of latitude by two minutes of longitude (2' x 2') or approximately 2 miles by 2 miles. The main source of shelter data for TENOS is the National Shelter Survey (NSS) file which is ordered and grouped by standard locations (RSAC) and/or FIPS (R, S, C, MCD Place) codes. Unfortunately in virtually all cases, these location codes do not correspond to the 2' x 2' grid area needed for TENOS. In addition, some NSS locations define less than a 2' x 2' grid and others describe an area far greater than a 2' x 2' grid area.

The effort described in this study was designed to collect available population and shelter data, to analyze that data, to examine appropriate

methodologies for enhancement of the number and quality of estimates of both blast and radiation shelter spaces within grid cells, and to suggest specific algorithms to be used to create these estimates. These improved estimates are to be contained in a grid file which is used by TENOS to assess facility damage and personnel casualties from nuclear attack.

II. OBJECTIVES

The primary objectives of this effort were to enable an improvement in the estimation procedure for developing data inputs to TENOS with respect to missing data and the distribution of shelter data among the cells of the existing gridding system. These objectives were realized by developing improved algorithms for estimating the following:

- Missing data which is known or believed firmly to exist but which are not contained in the NSS data base including:

  Mines (Code A) data
  Blast spaces
  Host area (fallout) spaces
  Home basement spaces

- Distribution of shelter spaces among grids within counties.

III. WORK PLAN

To achieve project objectives, RTI examined NSS and other data bases to assess the completeness of the shelter information used by the TENOS system, developed strategies to compensate for missing data required by the TENOS model, and developed both methodologies and algorithms to allocate the NSS shelter data to the 2' x 2' grid system used in TENOS.

Figure III-1 illustrates the work breakdown and organizational elements for the project. Tasks A and B were planned to support Task C through G by defining their data needs, identifying data sources, and analyzing selected samples of data. Five tasks, C through G, were planned to meet the specific analytical needs of the five areas defined in the statement of work. Task C focused on analyzing the results of previous allocation efforts and was intended to develop information for improved allocation procedures. Task D through G was intended to address the many shelter data problems associated with blast codes, mine (Code A) spaces, host area, and home basement spaces, respectively. Task H required information from all of the above in order to analyze the appropriate methodologies for effective resource allocation to grids. Finally, Tasks I, J, and K were planned to develop the recommended algorithms needed to achieve the objectives of this study. Task I addressed the resource allocation scheme. Task J addressed the various procedures to compensate for "missing data" in the NSS files for Code A, other blast protection codes, and host area shelter, respectively. Since home basement data was not to have been included in the NSS, Task K addresses the problem in estimating these spaces for population protection.

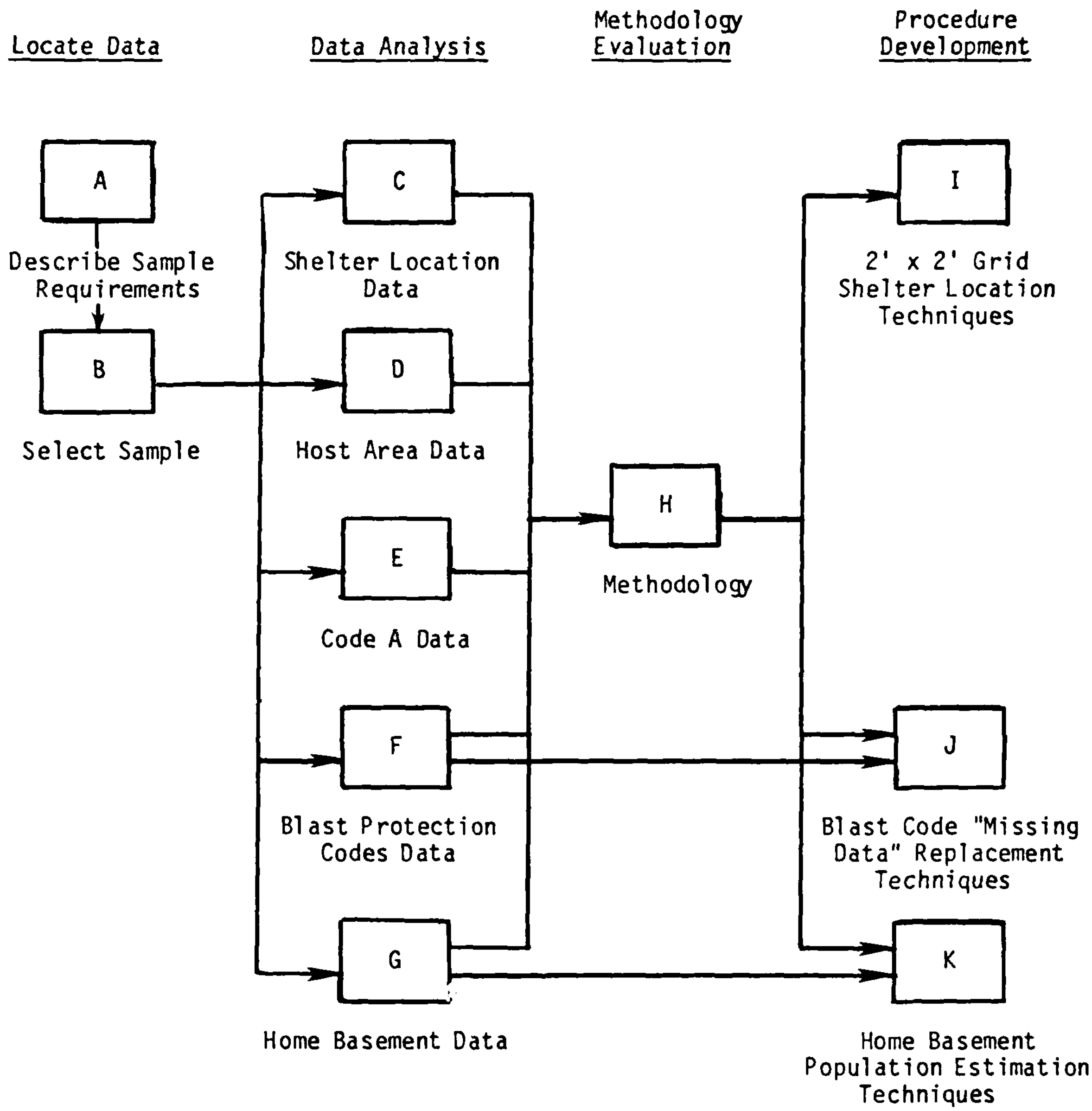

Figure III-1. Task Organization

Preliminary tasks required an examination of all available data sources for completeness of data concerning shelter location, host area shelters, blast type A structures, and other blast protection codes. The completeness of the data was assessed through examination of several samples of records drawn from the various files. The logical steps in selecting these samples proceeded from the initial consideration and development of the information requirements needed to satisfy the objectives of the study. In statistical terms, considerations in this respect involved the determination of the populations of interest and the population parameters to be estimated. Precision estimates required an amount of effort beyond the limits of available funds and, therefore, were not included.

A number of different samples from the data sources for the five areas were planned to support the specific needs of each task.

The primary data sources for shelter data was the NSS regional files and the county summaries from them. The primary data source for population data was the MEDList files. Samples of data were to be selected from these sources as a result of tasks A and B.

Sources of structures and population data outside the NSS file were used with the NSS data to help determine the "missing" shelter data and develop procedures to generate values as substitute data. These alternate sources of data included studies done at RTI such as a host area survey [1], mine survey [2], and blast analysis survey [3]. Strategies for completing the NSS data were based on analysis of the data in tasks D through G and J through K from the NSS file and the external sources with the use of special summary and statistical routines operating on the UNIVAC 1100/10 computer at Olney, MD.

These analyses were to be undertaken in tasks D through G to suggest means for estimating "missing" values.

Subsequent work in tasks C, H, and I addressed the problem of allocating shelter spaces to the 2' x 2' grid cells used in TENOS. Data in the NSS file were, in general, specific only to the level of the Standard Location Area (SLA) and had to be reallocated in a realistic way before its use by TENOS. Methods previously developed for reallocating population data from census tract to geographic grid level proved useful. Two such methods were employed by RTI in the Computer Assisted Area Source Emissions (CAASE) system [4], and in determining population estimates for the North Carolina Planning and Land Use Management (PLUM) information system [5]. These various allocation methods, along with simple uniform density and point source methods, were evaluated to determine which best fits the available data.

Implementation of this plan is described in the balance of this report. The results of Tasks A and B are described in Section IV, Tasks C through G in Section V, Task H in Section VI, and Tasks I through K in Section VII.

IV. BASE OF DATA

A. Files

1. National Shelter Survey (NSS)*

The major program used for identifying shelter in the U.S. was the National Fallout Shelter System (NFSS). The NFSS was started in 1961 and identified more than 250 million spaces in some 500,000 buildings. As shown in Table IV-1, the NFSS has gone through many changes over its 20 year lifetime. In 1970, the NFSS was changed to the National Shelter Survey (NSS) to reflect the addition of elements that were not just concerned with fallout radiation protection (such as blast protection, fire vulnerability, etc.). The concept of a Crisis Relocation Plan (CRP) was developed in the early 1970's that resulted in a pilot survey in 1973-74 and worked towards complete full scale surveying in 1975. As of the present time, many of the CRP designated host areas have not been surveyed and many of the risk areas have not been re-surveyed in many years. Current plans call for CRP completion in FY 1982 and CRP/NSS update completion by FY 1984.

Although incomplete, the NSS (which now includes NFSS, NSS, and CRP files) represents the best source of shelter data and serves as the foundation of the fallout and blast shelter resources available to the algorithms that estimate fallout and blast shelter to be used in the TENOS Grid file.

A Standard Location Area (SLA) summary of the NSS file to the SLA level was used in generating the TENOS grid data file. Much of the data in the NSS is "located" by the centroid location (latitude and longitude) of the SLA.

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* National Shelter Survey Instructions, Federal Emergency Management Agency, TR-84, May 1980.

TABLE IV-1. NFSS, NSS, CRP SURVEYS - CRITICAL DATES IN SURVEY CRITERIA AND IMPLEMENTATION

Date	Type	Phase 1 Survey Criteria*		Phase 2 Recording Criteria**		Remarks
		Minimum Spaces	Minimum PF	Minimum Spaces	Minimum PF	
1961	NFSS	50	20	50	As specified	Program started with NBS (FOSDIC) system used to calculate Phase 1 *PF*. 3 CFM *air requirement*; all facilities except single-family residences surveyed.
March, 1962	NFSS	50	20	50	100	Air requirement of 3 CFM, 10 spaces minimum per area in order to be recorded.
July, 1963	NFSS	50	20	50	40	Single-family residences included.
March, 1965	NFSS	50	20	50	40	Resurvey of shelter facilities for space in PF Categories 2 and 3.
June, 1965	NFSS	50	40	50	40/20	Drop surveying of single-family dwellings. Category 1 (PF 20-39) spaces added in *new* facilities (facility must contain Category 2 space).
June, 1966	NFSS	50	40	50	40/20	Category 1 space recorded only for facilities in deficit areas.
February, 1967	NFSS	50	40	50	40/20	PF-COMP *program* used to compute PF's and estimate shelter space.
May, 1967	NFSS	50	40	50	20	Category 1 space recorded for new facilities surveyed.
August, 1967	NFSS	50	20	50	10	Category 0 space added for *new* facilities surveyed.
July, 1969***	NFSS	10	40	50	10	Criteria for survey of deficit SL's only.
1970	NFSS/NSS****	10	20	10	20/10	Survery criterion changed to include smaller structures.
1973-1974	CRP	10	20	10	20/10	Pilot study of potential host area shelter.
1975-	CRP	10	20	10	20/10	Survey of CRP facilities near counterforce areas.
1979-1980	CRP	10	20	10	20/10	CRP survey extened to 21 other areas as funds permitted.
Future	NSS/CRP	10	20	10	20/10	CRP survey extened to 61 *more* areas. NSS update to be *performed after new* areas are surveyed for CRP.

* Estimated probably available in facility.
** Actually found in facility.
*** In addition to regular criterion of 50 spaces at PF = 20.
**** NFSS was restructured into the NSS (National Shelter Survey).

This code was based on the 1960 geographical location and has subsequently been redesignated as the newer "FIPS" codes (1970,1980). Since a latitude and longitude error of two minutes will put the shelter in a different grid, the shelter data (1960, 1970 location) may be separated from the population (1970, 1980 location) and a reallocation scheme will be necessary to get the population matched to shelter.

The content of the current NSS files are described in Appendix A.

2. <u>MEDList and Other Census Data</u>

MED-X* is the MEDList Extended with Geographic Coordinates which provides location of all geographic segments** of the MEDList. In particular, this file contains approximately 400,000 logical records for states, counties, minor civil divisions (MCD) or census county divisions (CCD), MCD/place segments (or CCD/place segments), enumeration districts, and blockgroups. The file is in sort order by state, county, MCD (or CCD), place, and then enumeration district (ED) and blockgroup (where applicable).

In tracted areas (within MCD/place segment where applicable and MCD elsewhere), the ED's blockgroups are presented in tract order with all the ED's in a tract preceding the blockgroups. Sometimes, however, all the ED's in the entire place segment or MCD are presented first in tract order followed by all the blockgroups in tract order. When this happens and there are tracts

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* A more complete list of the data elements can be found in the National Data Use and Access Laboratories 1970 Census Geographic Identification Code Scheme Tape Files - Technical Document GT-1., Dual Labs, Suite 915, 1411 Jefferson Davis Highway, Arlington, Virginia, 22202. July 1971.

** Further descriptions of the geographic area content can be found in the Census Users' Dictionary, published as part of the 1970 Census Users' Guide, Part I, Government Printing Office, Washington, D.C., 1970.

composed by both ED's and blockgroups, the ED and blockgroup parts of such tracts may not appear together.

Blockgroups that are split by MCD, place, congressional district, annexed territory, or urbanized area boundaries will have two or more records which are not likely to appear together. These blockgroup splits are indicated by a single or double asterisk following the blockgroup number. Where blockgroups are split by the city delivery area boundary line, the MEDList records for these blockgroups pertain only to the portion inside the city delivery area. The remainder of the blockgroup outside the city delivery area is combined with the ED in which it is located.

Outside tracted areas, ED's are sorted by MCD/place segment where applicable (including the MCD remainder) and MCD elsewhere. (See Appendix A, for file layout and code definition).

3. Dodge Reports

Shelter identification in existing buildings is highly dependent on knowledge of construction volume. In addition to the NSS and census data, RTI has used the Dodge Reports to develop a construction estimating procedure adaptable for use by national and local civil defense planners.

The Dodge Reports, published by the F. W. Dodge Company, a subsidiary of the McGraw-Hill Book Company, Inc., contain construction statistics such as number of stories, use class and ownership codes (NSS) floor area, number of dwelling units, valuation, and builder. The Dodge Reports for 1961-1965 were purchased by RTI and the coding for district, state, and county data was converted to the DCPA coding system. At the time of purchase, F. W. Dodge estimated that the statistical series of reports covered approximately 90 percent of all new construction, with a single report for each building. The

10 percent of construction not covered accounted for projects below $10,000, farm construction, and classified military operations. Also, at this time coverage of 13 western states was not as complete as that for the eastern section of the United States. The reports are updated on a continuing basis and published annually and the current (1981) reports contain the same essential data (see Appendix A).

For purposes of this project, the construction estimating procedure developed by RTI using the 1961-1965 Dodge Reports was used. However, corresponding data could be extracted from current reports to provide updated information.

4. Risk Areas

Crisis Relocation Plans require definitions of risk and host areas. Therefore, machine readable files exist, that are presently being updated, and define whether the population in any county in the United States is at risk or not at risk. In the latter two categories, counties not at risk may or may not be host counties. Host populations are defined by associating a set of risk or partial risk counties with a set of host counties either full or partial. This association is called a conglomerate. A hosting factor is established for each host county population in a conglomerate such that the sum of the products of the host county (or partial county) population and the hosting factor is equal to the population at risk. Counties that do not appear among the conglomerates are non-risk non-host counties. This information may be important in establishing an improved algorithm for distribution of shelter spaces.

The exact format of this file is unknown to those involved in this study. Since the algorithms developed herein are not being coded under this contract,

the precise layout of file records is not needed. However, it is important to know that using this file will permit all counties to be divided into the following categories:

(1) Risk - direct weapon effects expected

(2) Near Risk - that part of a county partially at risk which is not expecting direct weapon effects
or
- an area adjacent to a county fully or partially at risk
or
- a host county that may be at risk through retargeting after crisis relocation

(3) Host - no direct weapon effects and will host relocated population,

(4) Null - no direct weapon effects and will not host relocated population.

5. <u>Mine Data Files</u>

Three main sources of mine data (outside the NSS file itself), identified and used in this study, are described below.

RTI's <u>Development of an Underground Asset Survey</u> [2] undertook an exhaustive survey of available shelters in mines and caverns in New York and Vermont. In addition to providing survey techniques and reliable data on the two states visited, the study also provides an estimate of the quality of the Code A data contained in the NSS at that time. The RTI study also identified sources of information on mines. It was determined that the most reliable information on local mines could be obtained from state geologists.

The Mine Safety and Health Administration (MSHA) in the Department of Labor provides the most accurate list of currently active mines for both the RTI study above and for the current study. Computer readable tape files covering mines in the entire country are available through the Health and Safety Analysis Center, P.O. Box 25367, Denver, Colorado, 80225 (see MSHA Tape

Data File Description in Appendix A). Various listings prepared from these files are also available. Two types of files are maintained: accident and injury reports by year, and address and employment data. These are further divided into separate data bases for coal and for metal and non-metal mines. Employment data is given by work station (underground). Commodities are denoted by Standard Industrial Classification (SIC). Underground mines are identifiable by code. Tonnage and seam height are given for coal mines.

The Bureau of Mines (BM) in the Department of the Interior also maintains and distributes computer tapes of mine data in the Mineral Industry Locator Systems (MILS). Identification numbers for individual mines are compatible with MSHA files. It is felt that the MSHA files are probably more up to date and complete in listing currently active mines. However, the BM files contain excellent location data, hydrologic codes, type of access, etc. Data on tonnage and layout of mines is kept, but this information is proprietary and is not available on the computer tapes. Further information may be obtained from the Mineral Availability Section of the Bureau of Mines, Gary Kingston, 202-634-1026, or John Dillon, 303-234-6266.

6. Grid File

The TENOS grid file is the data base used in the TENOS assessment model. This file contains various identifying and location codes, shelter, population, and, when applicable, weapon effects estimates*. A listing of the elements that make up the grid file together with code definition are shown in Appendix A.

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* Weapon effects estimates imply that an attack has been levied on the grid file and various attack assumptions have been previously specified. (See Section IV.A.4 above).

The TENOS data base contains only grids (2" x 2") with population, shelter spaces or both. In this way the U.S. can be represented by approximately 110,000 grids instead of the 1,000,000 grids required to cover the entire U.S. with two-minute by two-minute cells. Of the 110,000 grids, approximately 22,000 are in non-CRP county areas, 11,000 are in CRP risk areas, 22,000 are in CRP near-risk areas, and 55,000 are in CRP host areas.

B. Sample Counties

A sample of ten counties, representing each of the ten national Civil Defense regions, was selected for further investigation. A list of these counties is shown in Table IV-2 and their location as well as the regional divisions can be seen in Figure IV-1. Four of the selected counties represent host counties, and the remaining six are classified as risk counties (including near-risk portions).

Figure IV-2 demonstrates an example of the data available in the TENOS data base, presented as grid maps. All maps are divided into two-minute grids overlaid with county outlines. Many of the grids are active, containing information relevant to population, shelter, and blast overpressure. In these gridded maps, population, shelter, and blast overpressure are designated as P, S, and B, respectively. Not obvious in Figure IV-2 are color codes representing the CRP status of each active grid. These designations as well as their accompanying values are color coded for CRP status. These four codes codes are defined as:

- Black: no-risk grids that contain shelter spaces but no population
- Green: no-risk grids that always include population, and frequently, shelter spaces
- Blue: no-risk grids expected to suffer very high fallout, such that people are moved neither in nor out of the gridded area.

TABLE IV-2. SAMPLE COUNTIES

Region	FIPS State	FIPS County	County Name	State Name	Latitude Min.	Latitude Max.	Longitude Min.	Longitude Max.	Standard Location	SL#	HC#*
01	25	015	Hampshire	Massachusetts	42°10"	42°34"	72°12"	73°04"	Springfield	8000	116
02	36	027	Dutchess	New York	73°28"	74°04"	41°26"	42°06"	Poughkeepsie	6460	---
03	24	031	Montgomery	Maryland	38°54"	39°22"	76°54"	77°34"	Washington	884	44
04	13	257	Stephens	Georgia	34°25"	34°44"	83°06"	83°28"			
05	26	125	Oakland	Michigan	42°26"	42°54"	83°04"	83°42"	Detroit	2160	120
06	48	029	Bexar	Texas	29°06"	29°46"	98°06"	98°50"	San Antonio	7240	242
07	29	097	Jasper	Missouri	37°02"	37°24"	94°02"	94°40"			
08	30	013	Cascade	Montana	46°48"	47°42"	110°36"	112°04"	Great Falls	3040	141
09	06	085	Stana Clara	California	36°52"	37°38"	121°12"	133°12"	San Jose	7400	25
10	53	077	Yakima	Washington	46°02"	49°06"	119°50"	121°32"	Yakima	9260	---

* HC Number is the Census of Housing document that contains data on this area. (Example CENSUS-70-HC(3)-116 describes the Springfield Mass. area that contains Hampshire County, Mass.).

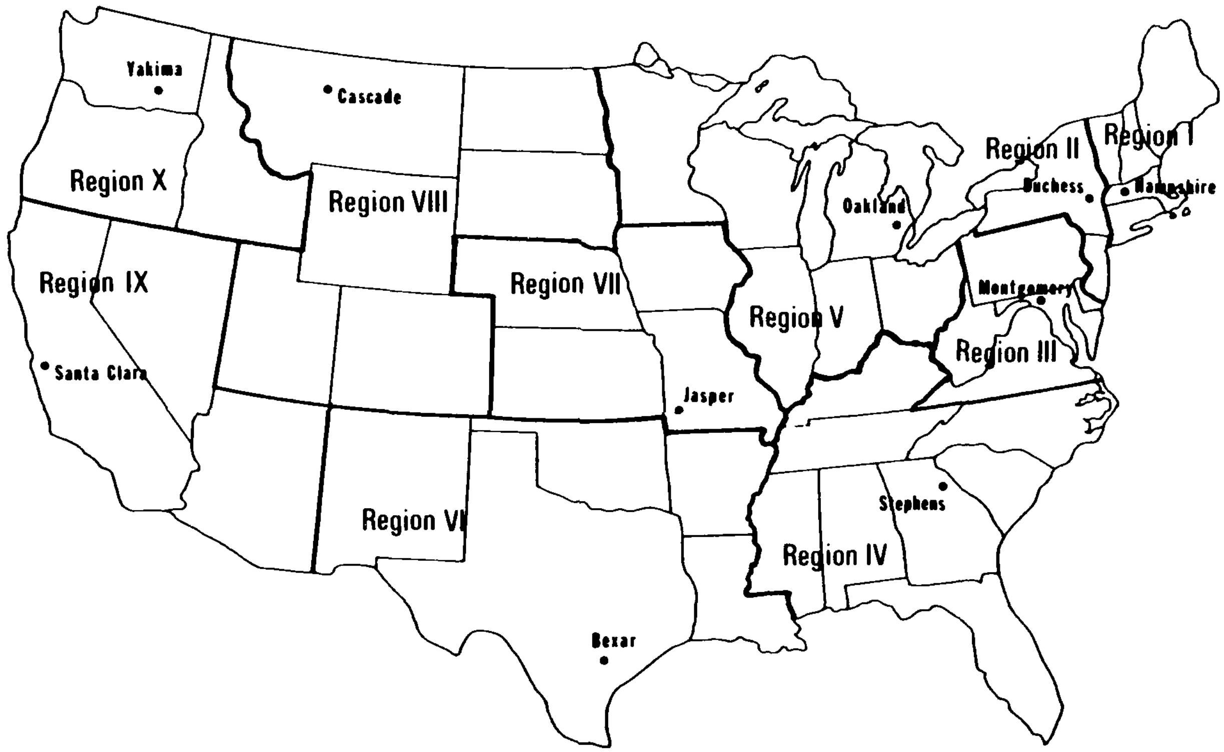


Figure IV-1. Location of Sample Counties and Regional Divisions

MONTGOMERY COUNTY, MARYLAND (24-031)

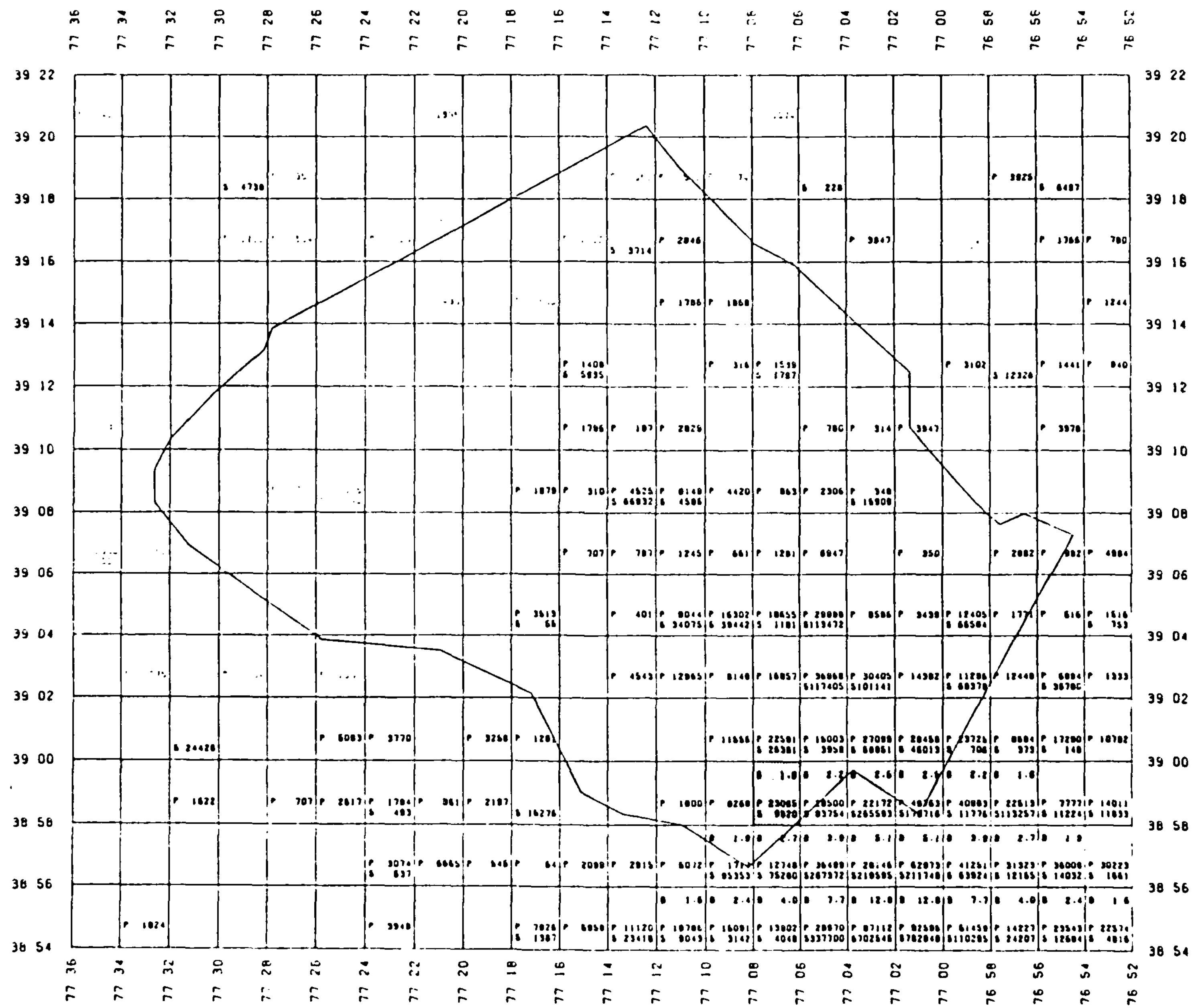


Figure IV-2. Example of TENOS Data

- Red: risk grid area expected to receive a blast overpressure of at least 1.8 psi.

In summary, the shaded grid of Figure IV-2 represents the general information available in the TENOS grid maps. The grid is a risk area and has a center location of 38° 59' by 77° 07', a population of 23,065, shelter spaces for 9,820 people, and overpressure of 1.8 psi.

V. DATA ANALYSIS

This section contains an analysis of the data described in Section IV as it pertains to building location and blast and radiation protection characteristics of shelter space within the building.

A. Building Locations

RTI obtained a plot of the grid file for the ten counties selected from the ten regions of the contigious states. These plots provided the basis for analyzing the facility location problems associated with the earlier methods used when generating the grid file for TENOS.

Interpretation of the CRP color codes discussed in Subsection IV-B is dependent on the status of the county being examined. For example, host counties contain only green and black codes. The entire area of these counties, therefore, represents a host zone. In Figure V-1, the shaded area outlines the host zone. The grids bordering the county outline are included as part of the host area if 50 percent of the grid area is located inside the county boundary.

Risk counties, however, often contain all four CRP color codes and, for purposes of statistical evaluation, are divided into two zones, near-risk and risk. The near-risk zone comprises green, black, and blue codes and acts as a host area to the risk zone containing only the red CRP code. In order to delineate the two zones, the centroids of risk (red) grids were connected with the controids of surrounding near-risk (green, blue, and black) grids by a straight line. These centroid lines were then bisected and the resulting midpoints were connected to form the zone outline. Shared grids were assigned

STEPHENS COUNTY, GEORGIA (13-257)

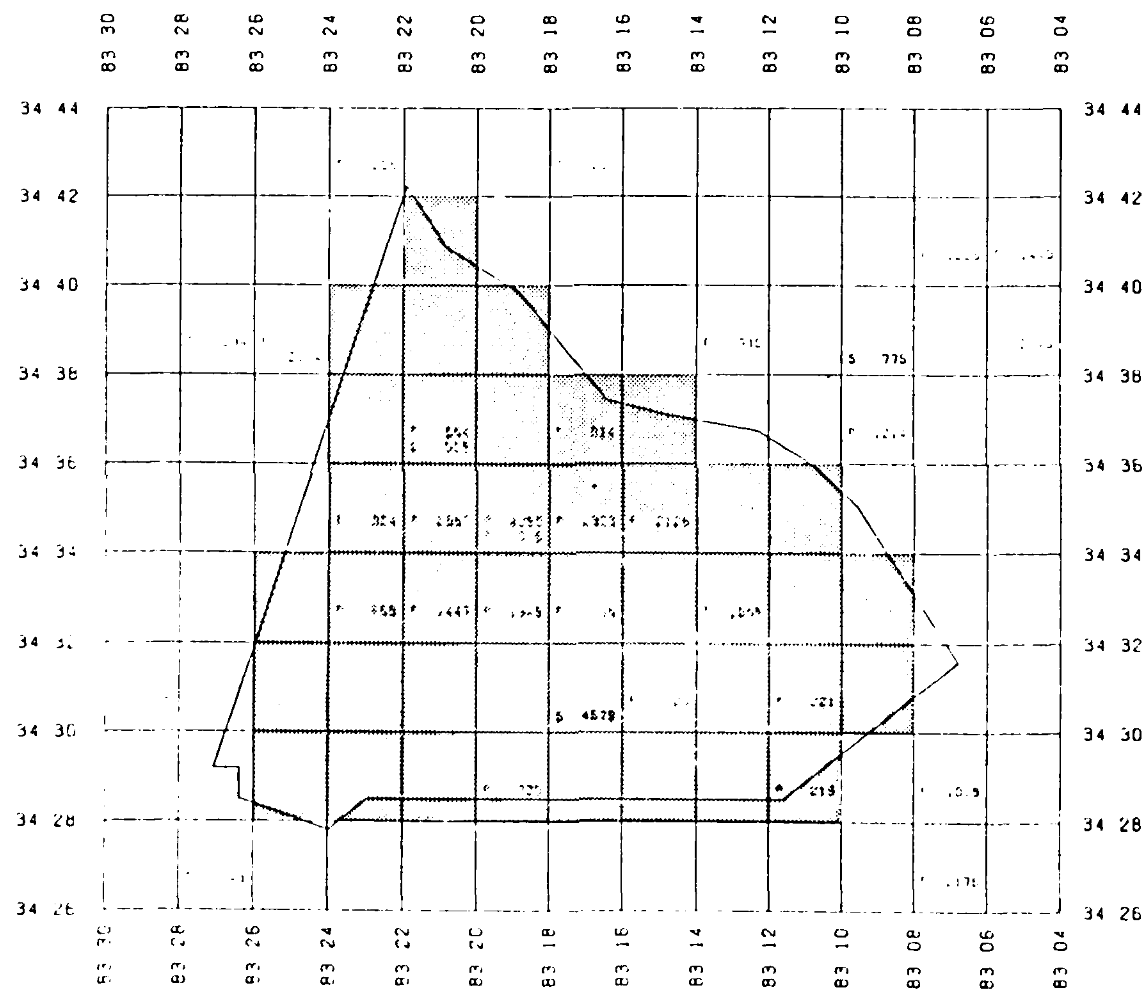


Figure V-1. Example of Host Data

to the zone containing over 50 percent of the grid area. An example of this procedure is demonstrated in Figure V-2.

Table V-1 shows comparisons between the three types of zones investigated in the ten county sample and includes an analysis of data provided by the TENOS grid maps. These calculations are represented graphically in Figures V-3 through V-8. Figure V-3 demonstrates the ratio of all non-blank or active grids to the total number of grids per zone type. Also shown is a breakdown of this category into the ratios of active grids having only population, both population and shelter, and only shelter spaces to the total number of grids per zone type. Not surprisingly, risk zones showed much higher values for population as well as population and shelter ratios than the other two zones. These results reflect the typical characteristics of a risk zone which tend to be highly developed urban areas maintaining a large population and, consequently, numerous buildings to accommodate this population. Host zone values were somewhat higher than near-risk zone figures, perhaps due to the clustering effect of suburban and industrial areas in the near-risk zones as opposed to the more scattered settlement pattern of a rural area. The ratio of grids containing only shelter spaces to the total number of grids was about equal for host and near-risk zones and at least twice that of risk zones. This is probably a result of population distribution throughout the zone grids which is fairly uniform in the risk zones but more localized into smaller areas for the host and near-risk zones.

Figure V-4 examines the percentage of accessible shelter spaces per person. These values were calculated without the application of a hosting factor. The hosting factor is based upon the ratio of the allocation of relocatees to the host population and is used to determine the population of

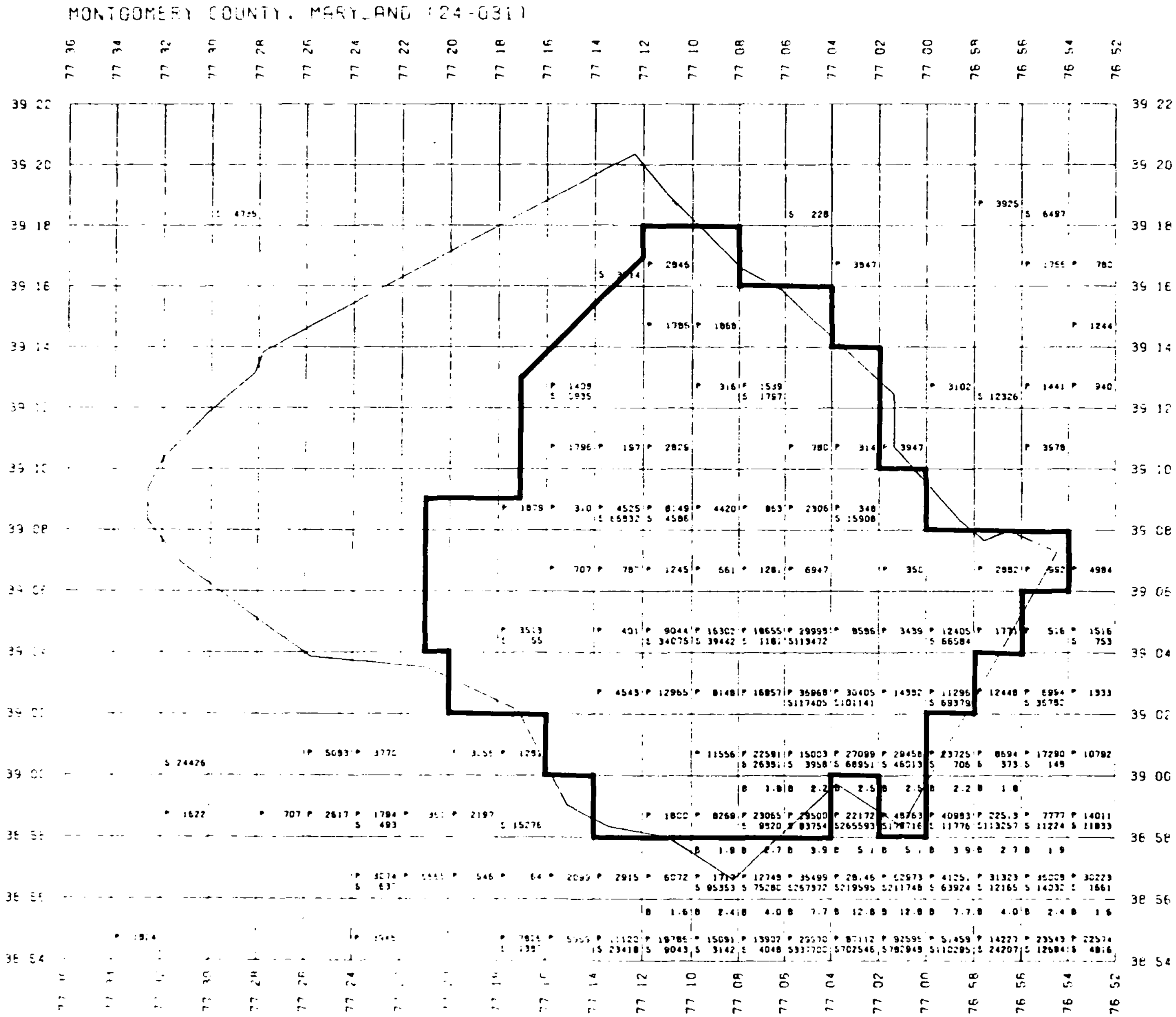


Figure V-2. Example of Near-Risk and Risk Zones

TABLE V-1. NON-BLANK TO TOTAL GRIDS (%)

Zone	Stat	Non-blank to Total Grids (%)				Spaces/ Person (%)	Black/ Total Spaces (%)	% Spaces Inaccessible	Ratio of Blank to Nonblank	Population Density
		Population Only	Population + Shelter	Shelter Only	Combined					
Host	Mean	27.75	4.75	2.00	34.50	48.75	40.75	53.25	1.40	577.18
	S.D.	16.32	2.87	1.41	19.96	31.36	41.86	32.85	0.58	421.07
Near-Risk	Mean	15.67	3.83	2.00	21.33	4.50	48.33	59.33	3.41	406.02
	S.D.	8.78	4.36	1.26	13.16	8.68	49.48	43.87	1.57	347.49
Risk	Mean	33.33	23.33	.83	57.33	101.00	-	-	.55	4,812.89
	S.D.	14.94	16.79	1.60	29.50	59.73	-	-	.35	3,487.47

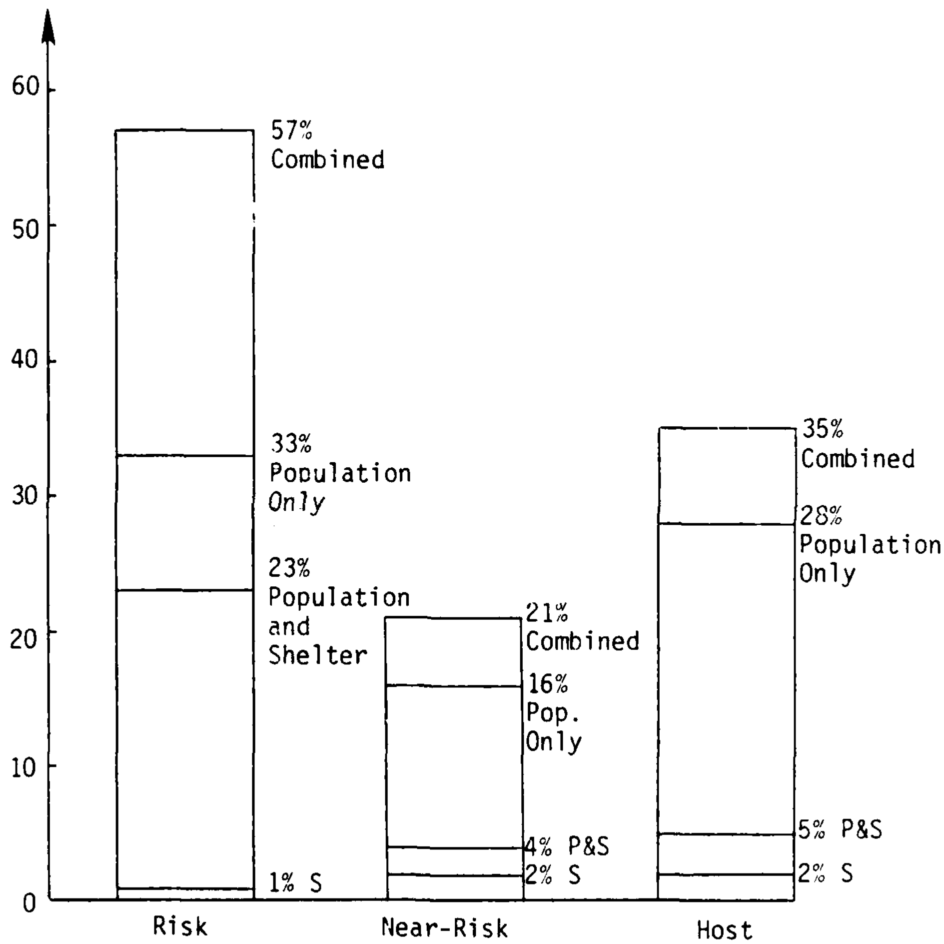


Figure V-3. Percent of Non-Blank Grids to Total Grids

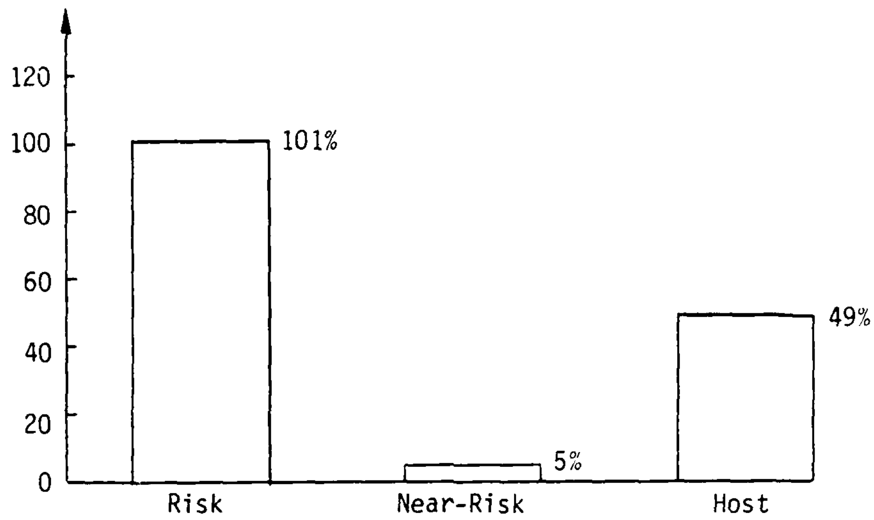


Figure V-4. Percent of Spaces to Population

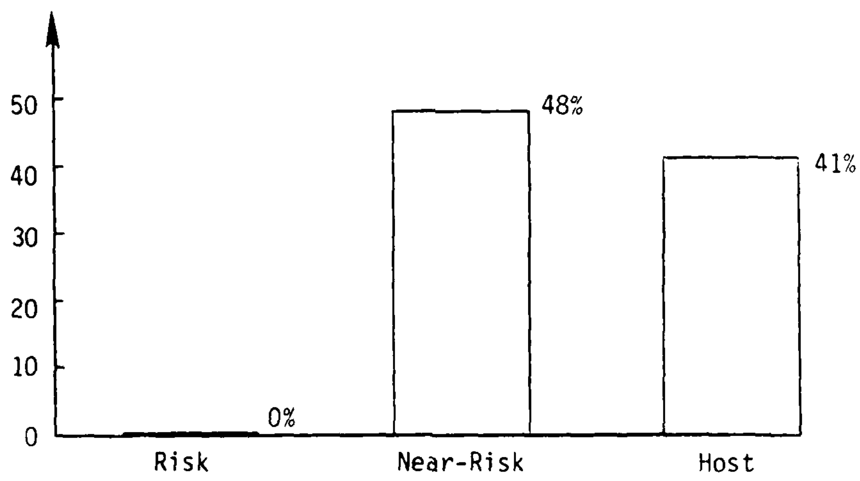


Figure V-5. Percent of Grids with Blank Spaces to Total Grids with Spaces

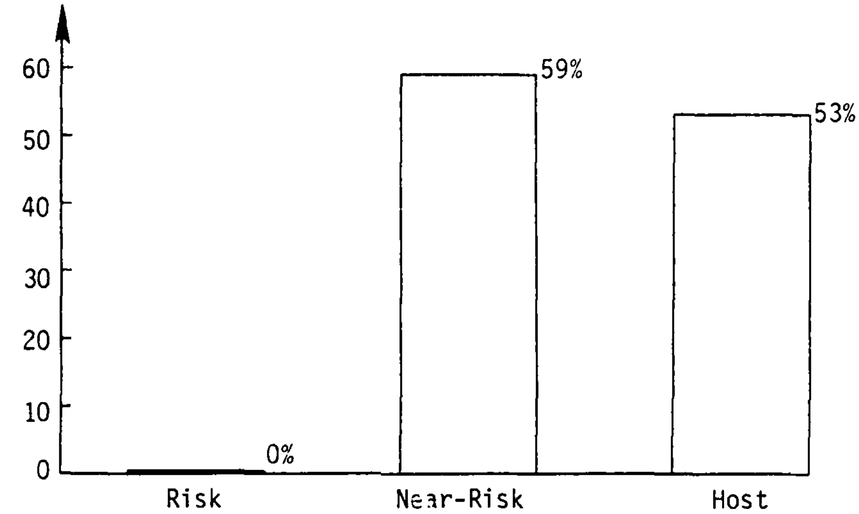


Figure V-6. Percent of Inaccessible Spaces

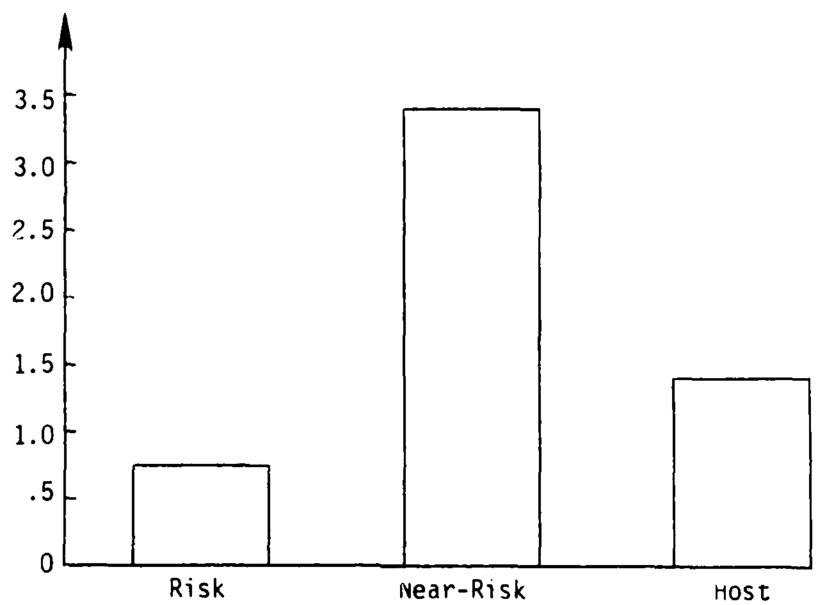


Figure V-7. Ratio of Blank Grids to Non-Blank Grids

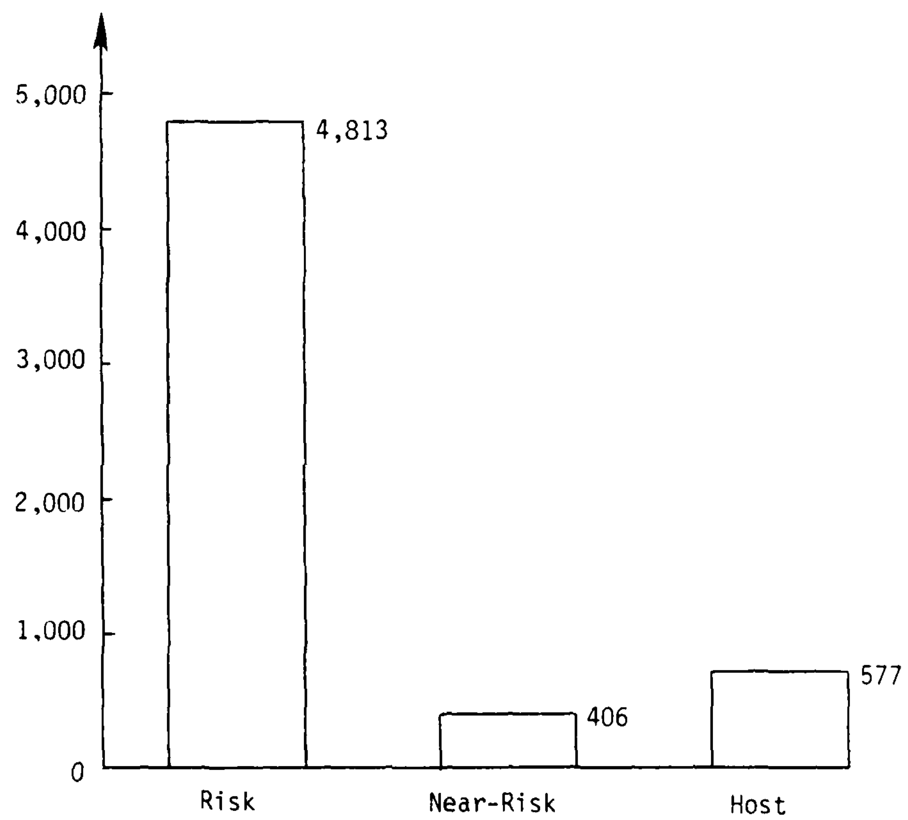


Figure V-8. Population Density

the host areas after relocation. As seen in Figure V-4, only the risk zones offered complete shelter for the population while values for host and near-risk zones were much lower.

Also calculated and shown in Figure V-5 was the ratio of shelter spaces located in grids having a black CRP code to the total number of shelter spaces. Table V-1 indicates that the ratio for both host and near-risk zones are about the same at 41 and 48 percents, respectively. Risk zones are necessarily void of these particular shelter spaces since, by definition, grids with a black CRP code are located in not-at-risk zones. In Figure V-6, the percentage of inaccessible shelter spaces was examined. Inaccessible shelter spaces are defined as those spaces which are not available as shelter to the population. This includes spaces in a grid area that remain vacant after relocation has been completed as well as shelter spaces occurring in black coded grids (since relocatees cannot be moved into zero-population grids). Values for host and near-risk zones were approximately the same. Risk zones were once again omitted from calculation since the hosting factor is applied only to hosting area data and no black coded grids are found in these zones.

Figure V-7 demonstrates the ratio of blank or nonactive grids to non-blank or active grids. Calculations show that the ratio is highest for near-risk zones, which is almost three times that of host zones and six times that of risk zones.

Population density, represented graphically in Figure V-8, shows an expected high concentration of population in risk zones, followed by much lower densities for host and near-risk zones.

B. Code A Data

1. Mines

RTI used secondary sources and knowledge of the chronological and philosophical environment of the special surveys to estimate the completeness and timeliness of the special facilities contained in the NSS.

Since special shelters (mines, caves, tunnels, etc.) have been generally surveyed and added to the NSS on a very irregular basis, their representation in the NSS was rather incomplete, although attempts have been made in the last few years to add these special facilities to the NSS, especially in high risk areas (as defined by the latest relocation attitude of civil defense).

In the Development of an Underground Assets Survey [2] study for DCPA, RTI conducted pilot surveys of available shelter space in the states of New York and Vermont. Table V-2 summarizes the shelter potential of the mines visited. The RTI study identified a total of 21 mines suitable for sheltering, 7 of which were not currently listed in the NSS file. It was found that of the 25 mines in New York and Vermont listed in the NSS, 11 were abandoned and no longer suitable for sheltering.

Table V-2 also compares the shelter spaces identified in the RTI study with those in the then-current NSS. Although these estimates vary by a factor of 3, the RTI space estimates were an average of 2 times those on the NSS file for mines identified in both studies.

A listing from the MSHA file in 1976 [2] was used to compare employment data to the shelter space counts. As indicated in Table V-2, not much correlation exists between number of employees and available shelter space. Perhaps with a finer breakdown into underground employees, mill hands, etc., better correlation could be achieved.

TABLE V-2. SHELTER SPACES IN MINES
NEW YORK AND VERMONT BY COUNTY

State	County	Mine (RTI id.)*	NSS** Spaces	RTI* Spaces	RTI* Status	MSHA*** Status	MSHA*** No. Workers	Ratio RTI Spaces/ NSS Spaces	Ratio RTI Spaces/ MSHA Workers
New York	Clinton	18	24,000	13,213	Active			0.542	
	Columbos	34	--	1,542	Storage				
	Cortland	16 (see #5)	--	--	Duplicate Listing				
	Erie	2	11,333	--	Shutdown				
		8	23,333	--	Shutdown				
		30	--	--	Abandoned				
		38	--	--	Abandoned				
	Essex	6	3,785	11,400	Active	Active	52	3.012	219.2
		35	--	17,600	Active				
		41	--	--	Abandoned				
		45	--	--	Abandoned				
	Genessee	15	--	41,600	Active				
	Jefferson	40			Open Pit				
	Livingston	5	10,925	41,860	Active			3.832	
		36-37 (see #5)			Duplicate Listing				
	St. Lawrence	3	1,000	352	Active	Active	170	0.352	2.07
		4	1,200	7,000	Active	Temp. Closed	17	5.833	411.8
		10	--	308	Active	Active	7		44.0
		11	1,200	14,080	Active	Active	98	11.733	143.7
		12-14	--	37,267	Active	Active	540		69.01
		29	--	107	Active				
	Schohowie	28	4,500	880	Natural Cavern			0.196	
		48	480	80	Natural Cavern			0.167	
	Sullivan	44	505	--	Abandoned				
	Tompkins	1	--	10,125	Active				
	Ulster	17	24,400	13,213	Active			0.542	
		31	--	--	Abandoned				
		32	--	--	Abandoned				
		43	8,280	--	Abandoned				
		46	1,800	--	Abandoned				
		47 (see #17)	15,000	--	Duplicate Listing				
		49	52,600	34,848	Active			0.663	
		50	--	--	Abandoned				

(Continued)

TABLE V-2. SHELTER SPACES IN MINES
NEW YORK AND VERMONT BY COUNTY (Continued)

State	County	Mine (RTI id.)*	NSS** Spaces	RTI* Spaces	RTI* Status	MSHA*** Status	MSHA*** No. Workers	Ratio RTI Spaces/ NSS Spaces	Ratio RTI Spaces/ MSHA Workers
New York	Warren	42	--	--	Abandoned				
	Yates	7	--	90,510	Active				
	(Unknown)	33	--	--	Abandoned				
		39	2,000	--	Abandoned				
Vermont	Lamoille	19	2,000	864	Active	Active	55	0.432	15.7
	Orange	52	134	--	Abandoned				
	Rutland	20	3,200	--	Abandoned				
		21	30,000	20,700	Active	Active	46	0.690	450.0
		22	10,140	--	Abandoned				
		23	2,520	--	Abandoned				
		51	6,900	--	Abandoned				
	Windham	24	786	927	Active	Active	10	1.179	92.70
	Windsor	25-27	--	--	Refused Entry	Active	49		
							Average =	2.244 ± 3.332	160.9 ± 167.1

* As used in RTI Underground Assets Survey, 1976 [1].
** From NSS file at time of RTI 1976 study.
*** MSHA status, workers from 1977 list of active mines [2].

In the absence of better correlation between mine spaces and some available mine parameter, a coarse approximation may be obtained by using the mean number of spaces per mine by region. Table V-3 was completed by region from NSS data for mines (see Appendix A). It can be seen that there is wide variation among regions, as seen by comparing the means and standard deviations. Table V-4 indicates that except for the very small spaces/mine group the Category 4+ represent over 90 percent of all spaces with the balance being largely in Category 2-3.

If the Coefficient of Variation (α/μ) is used as an indicator of the value of grouping by average size, then smaller coefficients are better than larger ones. Grouping regions as shown in Table V-4 produces significantly smaller CVs than using national averages. Similarly, regional values based on average state values are believed to yield better average estimates of spaces per mine.

2. Highway Systems (Tunnels)

A possible source of rural fallout shelter space may be found in tunnels, drainage culverts, and cattle passes on primary and state secondary highway systems.

Consideration should be given to the possible use of large (over 20 square feet) pipe or box culverts and cattle passes under roadway embankments. These culverts usually extend a significant distance beyond the edge of the roadway shoulder, and the dimension from headwall to headwall is usually large compared with the cross sectional area. The total thickness of pavement, earth embankment and top slab of the culvert would exceed three feet in most cases.

TABLE V-3. ESTIMATES OF MINE SPACES AVAILABLE BY REGION

Region	Mines	PF 0		PF 1		PF 2-3		PF 4+	
		Total Spaces	Spaces Per Mine	Total Spaces	Spaces Per Mine	Total Spaces	Spaces Per Mine	Total Spaces	Spaces Per Mine
1	7	0	0	0	0	7	1	31,801	4,543
2	13	0	0	25	2	36	2	177,697	13,669
3	138	0	0	3,847	28	91,671	664	1,106,224	8,016
4	190	8,601	45	17,490	92	70,979	374	1,594,211	8,391
5	74	1,595	22	9,241	125	23,273	315	888,753	12,010
6	56	15	0	1,830	33	6,629	118	330,091	5,894
7	59	0	0	24,704	419	24,547	416	583,969	9,898
8	465	0	0	298	1	166,230	357	203,400	437
9	368	7,441	20	9,566	26	86,757	236	141,722	385
10	84	480	6	1,233	15	646	8	244,346	2,009
Total	1,454	1,813	μ=9.3 σ=15.2	6,823	μ=74.1 σ=128.0	47,077	μ=249.1 σ=218.5	530,221	μ=6,615.2 σ=4,598.2

TABLE V-4. GROUP COMPARISONS

	All Categories				
				PF 4+ Category	
Group (Spaces/Mine)	Region	Mean Spaces Per Mine	CV* σ/μ	Spaces Mean %	CV* α/μ
Very small <1,000	8,9	731	.12	56.4	.09
Small >1,000 <5,000	1,10	3,741	.30	99.5	.31
Medium >5,000 <10,000	3,4,6	7,885	.20	94.6	.20
Large >10,000	2,5,7	12,293	.12	96.2	.16
	All	6,947	.67	95.2	.70

* Coefficient of variation, CV = σ/μ

The Federal Highway Administration, Department of Transportation, requested all State Highway Commissions to prepare "Structural Inventory and Appraisal of Bridges on the Federal Aid System." This inventory contains eighty-four data elements on each bridge (including culverts and tunnels) on federal aid highways throughout the United States. Bridges both going over and carrying federal aid highways were inventoried. For bridges on defense highways, a physical vulnerability code, similar to that used by FEMA, was assigned.

In North Carolina, the Bridge Maintenance Department of the N.C. Highway Commission prepared the required structural inventory and appraisal of bridges. A "Structural Inventory and Appraisal Sheet" was prepared to provide pertinent elements of information for each individual structure. The eighty-four coded data items on each sheet include county, coordinate location, city or town, highway designation, physical vulnerability, year of construction, span lengths, width, clearance, design load, skew angle, type of deck, superstructure, substructure, and condition of the bridge. The inventory also includes single and multiple barrel box or pipe culverts over twenty feet wide (measured along the center line of the roadway) and all highway tunnels. The N.C. Highway Commission completed a condition inspection and inventory of all 8,000 Federal Aid System structures to prepare the structural inventory and appraisal sheets and also input sheets for a computer storage and retrieval system.

In addition to these records, a number of states maintain other structural tabulations of highway bridges and culverts data similar to that described above for North Carolina. The Planning and Research Department of the North Carolina Highway Commission maintains bridge data on the Interstate

System, Federal Aid Primary System, and State Primary System. Although the Federal and State Secondary Systems include more highway mileage, it is probable that a larger shelter potential exists within the major systems for which bridge data records are maintained.

The data include design loading, bridge length, roadway width, vertical clearance, crossing identification and brief description of bridge type. This information is on computer cards and tape. Because most states have used standard bridge designs, it is likely that most bridges within a given state can be readily categorized.

A document entitled "Bridge Record for Defense Requirements" is prepared by each state each year on all Federal Aid Primary bridges for the Department of the Army. This document contains similar data to those maintained by the North Carolina Highway Commission. The obvious advantage of this source would be that data would be available at a single source for all states.

A filing system for all bridges on the State Highway System was also prepared, with an individual folder for each bridge containing an inspection sheet, Structural Inventory and Appraisal Sheet, two photographs, design computations, maintenance records and other particulars relating to the structure. This filing system contains approximately 16,000 structures.

The potential for new shelter space that could be built into future bridge overpasses has been examined on a cost per square foot basis in previous reports for FEMA. In order to realize this potential, it would be necessary, during the construction stage, to eliminate the slope wall, level and pave the surface and provide three protective walls and several entranceways at each bridge abutment.

Projections of future bridge and highway construction can be made through data available from Engineering News Record, Dodge Reports, and other construction cost sources. Major assistance could be obtained from the Federal Highway Administration, Department of Transportation.

In their unmodified state, the amount of protection provided by culverts is significant. Assuming a 6-foot by 6-foot opening, a 40-foot culvert has a PF of about 20 at its midpoint and a 100-foot culvert has a PF of about 65 at its midpoint. However, the use of culverts as shelter needs further evaluation from a hydrological point of view. If habitability is not a problem, expedient modifications may be defined for improving the protection in these facilities if required.

Highway tunnels should be much better than culverts in both habitability and protection. They are usually long enough to obtain a high PF at their midpoint. Assuming a 25-foot by 15-foot opening, a 200-foot tunnel has a PF of about 40 at its midpoint, and, of course, higher protection levels are obtained for longer lengths.

Thus, from structural data generally available, the NSS could potentially be updated to include rural shelter space found in tunnels, drainage culverts, and cattle passes on federal aid and state primary highway systems and possibly those on federal aid and state secondary systems. Extra spaces that could be obtained from expedient modifications might also be estimated for planning purposes. However, due to uncertainties associated with hydrological aspects of drainage culverts, which probably contain, collectively, the great majority of shelter spaces, no algorithm is currently proposed for implementing adjustments to NSS data for these special, Code A facilities.

C. Home Basements

The major information source for estimating home basement shelter availability, outside of U.S. Bureau of the Census housing and population reports, is the Home Fallout Protection Survey (HFPS). HFPS was instituted by FEMA's predecessor in 1966 to provide homeowners with information on the shelter potential in their own basements. Before being discontinued, the survey was conducted in 26 states, the District of Columbia, and portions of New York. The effort identified 30 million homes with basements that could provide some degree of protection for the 93 million occupants of these homes. If homeowners agreed to share their basements, several times as many people could be sheltered, to relieve greatly the shelter problem in many areas.

Although most home basements have PF Category 0 or 1 shelter (PF 10-39), expedient modifications could improve the protection to higher levels. These modifications could consist of piling earth against exposed basement walls and on the floor of the first story. However, detailed instructions to homeowners on methods of providing additional floor support would be needed.

The method devised for making this estimate utilizes data from the 1960, 1970 and 1980 census of population and housing. These data are extrapolated to the year of interest, assuming a semi-parabolic (or linear) curve that follows the trend established from the three census figures. The number of persons per household is obtained from the 1980 census of housing report. The estimated population is divided by the persons per household to determine the number of households. This number is multiplied by the ratio of housing units to households to obtain the number of housing units. This procedure is illustrated in Table V-5 for the Darvills District of Dinwiddie County, Virginia, the part of the county used for a detailed field survey in a 1973

TABLE V-5. ESTIMATE OF PRIVATE HOMES IN DARVILLS DISTRICT OF DINWIDDIE COUNTY FROM BUREAU OF CENSUS DATA

Year	Population	Persons Per Household	Households	Housing Units	Actual Field Count
1940	2965				
1950	2270				
1960	2097				
1970	1839	3.62	508	543	
1972*	1787	3.62	494	528Δ	547

* 1972 population estimates consider the decreased population trend and 3.62 persons per household in Darvills District.

Δ The number of housing units was assumed equal to 1.07 x number of households, which was determined from 1970 census data for all of Dinwiddie County.

The estimate of housing units in the Darvills District of Dinwiddie County is given below:

1960 Population: 2,097

1970 Population: 1,839

Population Change: -258

The population decrease estimated for 1970 through 1972 is 20 percent of 258 or 52 persons, giving:

1972 estimated population: 1,787

Persons per household, 1970: 3.62

Estimated Households, 1972: 1,787/3.62 = 494

Ratio of housing units to households, 1970: 1.07

Estimated housing units, 1970: 494 x 1.07 = 528

study [6], where 1960 and 1970 census figures were the basis of straight line extrapolation. This basic approach is used in Section VII.B.3 to develop a procedure to estimate available house basement shelter spaces independent of NSS Code D data.

D. Host Area

The primary reasons for anticipating "missing data" in fallout shelter surveys are due to the changes in survey philosophy (such as in-place population versus population relocation) and the lack of an intensive update of the NSS in the last five to ten years.

Specifically, using chronological information, shelter completeness studies, intensive shelter studies, host area studies, and other special shelter studies RTI devised a model to estimate the number of shelters likely to be found in a county if it were brought up to "resurveyed" status.

The analysis of the fallout shelter "missing data" is contained in the following three subsections. First, the data were analyzed with regard to the methods for estimating the missing shelter spaces in general. Next, these methods were applied to existing NSS buildings file as if it were updated. Finally, the analysis included estimates to buildings not in the NSS.

1. Estimating Additional Shelter in NSS Facilities

During Phase 1 of the NSS, buildings were surveyed which, in the judgment of the surveyor, met the survey criteria. In many cases, Protection Factor (PF) analysis showed that the building did not satisfy all of the requirements. These buildings were not included in Phase 2 of the NSS and consequently have no spaces recorded in the file; however, the structural data recorded in Phase 1 were maintained in the files. Existing computer programs

can extract this information for these buildings and perform a PF analysis on them to identify their shelter potential in all PF categories.

The technique for estimating additional shelter spaces in the lower PF categories for Phase 2 buildings currently listed as containing spaces in the NSS files incorporates variations to account for the time period in which the building was last surveyed. For buildings last surveyed prior to July, 1963, only Category 4 through 8 spaces are contained in the files and estimates of spaces in Categories 2 and 3, 1, and 0 need to be made. Buildings last surveyed from July, 1963 through May, 1965 have spaces in Categories 2 through 8 recorded and need estimates of spaces in Categories 1 and 0. Buildings surveyed from June, 1965 through July, 1967, had spaces in PF Category 1 recorded in addition to those in Categories 2 through 8. Estimates are required only for Category 0 spaces. Buildings surveyed in August, 1967, and later have spaces recorded in all PF categories on all stories.

For all buildings surveyed under the NBS FOSDIC system (before February, 1967), the estimating equations have a factor of 0.90 in them. This is to account for the 11 percent average overestimate of spaces in Categories 1 through 8 as determined in an earlier RTI research study [3].

The estimating procedure may be applied on a county basis if, for planning purposes, one is interested in the total spaces in the county, or it may be applied on a building by building basis if shelter allocation plans are being prepared. In either application, the information from the NSS files identified in Table V-6 is needed for the buildings for which estimates are to be made. The data may apply to a single building or collectively to a group of buildings. If estimates are to be made for a single building, only one survey date will apply, of course, and all other entries will be zero.

TABLE V-6. DATA NEEDED FROM NSS FILES

Date of Last Survey	n	Number of Spaces: Category 4-8	Category 2-3	Category 1	Category 0
Before July 1963	1	xxxx			
July 1963-May 1965	2	xxxx	xxxx		
June 1965-January 1967	3	xxxx	xxxx	xxxx	
February 1967-July 1967	4	xxxx	xxxx	xxxx	
August 1967 or later	5	xxxx	xxxx	xxxx	xxxx

The following equations are used to estimate the number of spaces in various PF categories using the information above. The equations immediately below apply to those buildings which have spaces recorded in the file in Categories 4 through 8 only.

(1) To estimate spaces in Categories 4 through 8:

$$\text{Cat. 4-8} = 0.90 \sum_{n=1}^{3} (\text{Cat. 4-8}) + \sum_{n=4}^{5} (\text{Cat. 4-8})$$

(2) To estimate spaces in Categories 2 and 3:

$$\text{Cat. 2-3} = 0.90K_1 \sum_{n=1} (\text{Cat. 4-8}) + 0.90 \sum_{n=2}^{3} (\text{Cat. 2-3})$$

$$+ \sum_{n=4}^{5} (\text{Cat. 2-3})$$

(3) To estimate spaces in Category 1:

$$\text{Cat. 1} = 0.90K_2 \sum_{n=1} (\text{Cat. 4-8}) + 0.90K_3 \sum_{n=2} (\text{Cat. 2-3})$$

$$+ 0.90 \sum_{n=3} (\text{Cat. 1}) + \sum_{n=4}^{5} (\text{Cat. 1})$$

(4) To estimate spaces in Category 0:

$$\text{Cat. 0} = 0.90K_4 \sum_{n=1} (\text{Cat. 4-8}) + 0.90K_5 \sum_{n=2} (\text{Cat. 2-3})$$

$$+ 0.90K_6 \sum_{n=3} (\text{Cat. 1}) + K_6 \sum_{n=4} (\text{Cat. 1}) + \sum_{n=5} (\text{Cat. 0})$$

In buildings for which the total number of spaces in Categories 2 through 8 are recorded, but no additional information is available, the following equations are to be used.

(5) To estimate spaces in Categories 4 through 8:

$$\text{Cat. 4-8} = 0.90K_7 \sum_{n=1}^{3} (\text{Cat. 2-8}) + K_7 \sum_{n=4}^{5} (\text{Cat. 2-8})$$

(6) To estimate spaces in Categories 2 and 3:

$$\text{Cat. 2-3} = 0.90K_8 \sum_{n=1}^{3} (\text{Cat. 2-8}) + K_8 \sum_{n=4}^{5} (\text{Cat. 2-8})$$

(7) To estimate spaces in Category 1:

$$\text{Cat. 1} = 0.90K_9 \sum_{n=1}^{3} (\text{Cat. 2-8}) + K_9 \sum_{n=4}^{5} (\text{Cat. 2-8})$$

(8) To estimate spaces in Category 0:

$$\text{Cat. 0} = 0.90K_{10} \sum_{n=1}^{3} (\text{Cat. 2-8}) + K_{10} \sum_{n=4}^{5} (\text{Cat. 2-8})$$

The constants in the above equation (K_1 through K_{10}) are ratios of spaces in the various PF categories and were obtained from a sample of facilities in the NSS. Values for the constants are given in Table V-7.

2. Estimating Spaces Gained by Increased Ventilation

The number of fallout spaces recorded for NSS buildings, whether in host or risk areas, is limited by the smaller of

- Spaces based on usable area
- Spaces based on available ventilation.

TABLE V-7. VALUES OF CONSTANTS USED IN ESTIMATING EQUATIONS

$K_1 = 1.76$	$K_6 = 1.15$
$K_2 = 1.80$	$K_7 = 0.36$
$K_3 = 1.02$	$K_8 = 0.64$
$K_4 = 2.07$	$K_9 = 0.65$
$K_5 = 1.18$	$K_{10} = 0.75$

Thus the limiting effective area for air movement was always used to determine the portion of the area in which shelter spaces are located.

RTI is currently involved in a study to generate the cost-optimal distribution of two predominant types of manually powered ventilators, Packaged Ventilation Kits (PVK's) and Kearney pumps, in the risk and host counterforce areas. (Due to the vulnerability of these mechanical devices to high overpressure, the ventilation kits are assumed to be double-stocked in risk areas.) This distribution will provide for adequate ventilation where the surveyor has indicated natural ventilation is inadequate, thus limiting the number of shelter spaces to less than would otherwise be available. Once the proper mix of devices are in place for a given shelter area, the available spaces in that story can be recalculated based on usable area only, thus resulting in an increase.

Regardless of the floor area in which shelter spaces are located, the NSS surveyor first determined the radiation protection in a structure by the Estimating and Analyzing Shelter Yield (EASY II) method through the use of the EASY II Graphical Solution Form. This completed form made the protection factor (PF) computation solution immediately available for entry to the NSS-CRP Data Input Form and was retained as a permanent record of the PF evaluation.

Thus, if enough ventilation can be provided for a shelter story area where natural ventilation is inadequate, the spaces for that story area, broken down into the various PF categories, can be recalculated based on the usable floor area from the resultant factors found on the completed EASY II Graphical Solution Form. An increase in shelter spaces in the story area would result. The current study of cost-optimized counterforce conglomerate

distribution of ventilation kits and Kearney pumps should give a good indicator of the feasibility of providing an adequate supply of such devices. The usable floor area itself, however, is recorded only for CRP facilities on the NSS-CRP Master File, and the surveyor did not include any information for NSS facilities on the NSS-CRP Data Input Form from which usable floor area by story can be calculated directly. In risk areas the information may be available from the Natural Ventilation Survey or the Direct Effects Data Collection Form, both completed simultaneously with the NSS, and facilities that qualify as NSS in host areas are also considered CRP facilities, meaning that usable floor area is recorded. The EASY II method itself was set up as a manual procedure based on the corresponding Graphical Solution Form, and it is currently unclear whether the procedure followed by the surveyors in using this form can be simulated in a straightforward manner.

3. Estimating Shelter Yield From an NSS Update

According to a 1973 study [6], based on a three-month interval of data from Dodge Reports during 1961-1965, thirty percent of the one-story buildings, thirty-five percent of the two-story buildings and sixty-seven percent of buildings with three or more stories are assumed to have basements. In the same study, nine percent of one-story buildings, twenty-one percent of two-story buildings, seventy-five percent of three-story buildings, and ninety-nine percent of buildings with four or more stories are assumed to meet NSS criteria.

In estimating the number of buildings with basements and those distributed by number of stories which would meet NSS criteria, conservatism is maintained by giving first priority to buildings without basements and

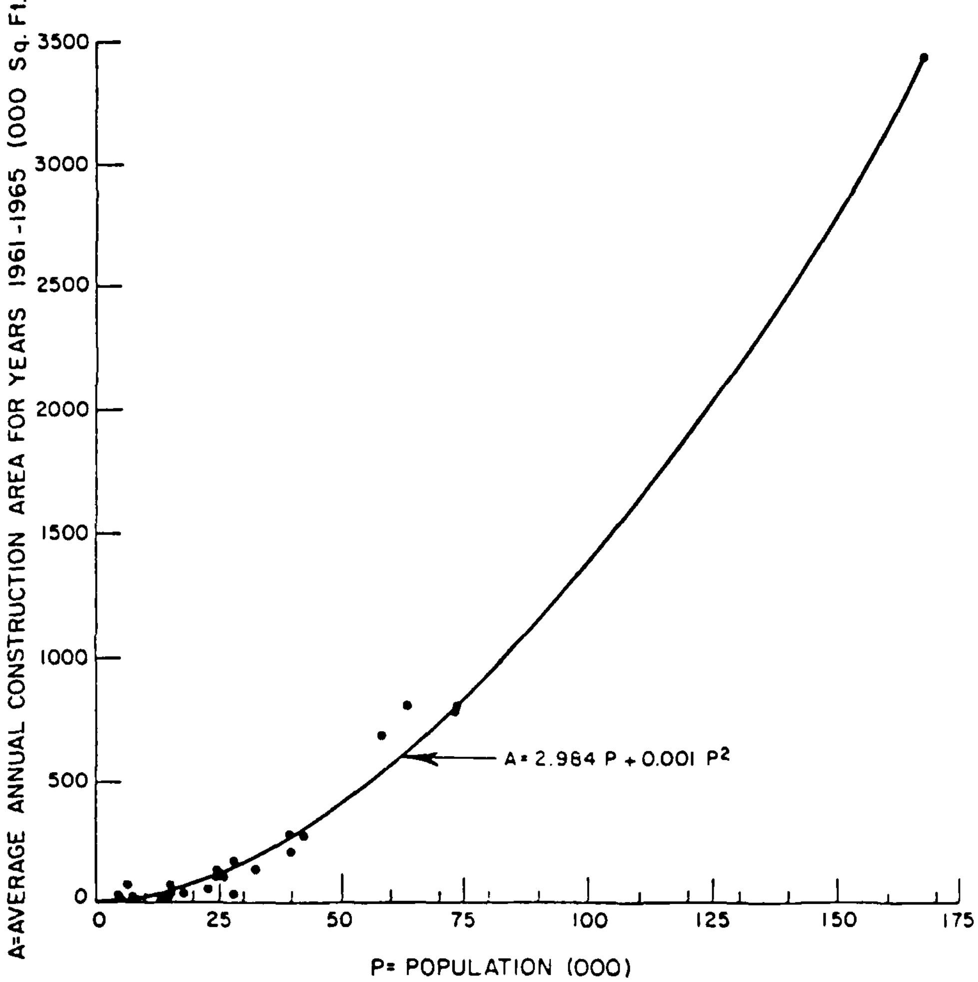
buildings which do not qualify for the NSS. For example, since only thirty percent of one-story buildings have basements, the first three one-story buildings in the county are assumed to be without basements. If only three one-story buildings are estimated to be built, all are assumed to be without basements.

4. Estimating Shelter Availability in Non-NSS Buildings

One of the major untapped resources for fallout shelters is the basements of buildings which do not qualify as NSS facilities because of either their small size or their low PF. In many rural areas where fallout levels are expected to be low, these facilities may provide significant life-saving potential. Damage limiting studies by FEMA indicate that a PF of 5 would be adequate to save lives in many areas. In areas where the existing fallout protection in these small buildings is not adequate, the PF can be upgraded to the required value in many of them through expedient alterations. These expedient alterations could consist of simple operations such as piling earth against exposed basement walls and on the floor above the basement. However, additional support for the floor would be required in most instances.

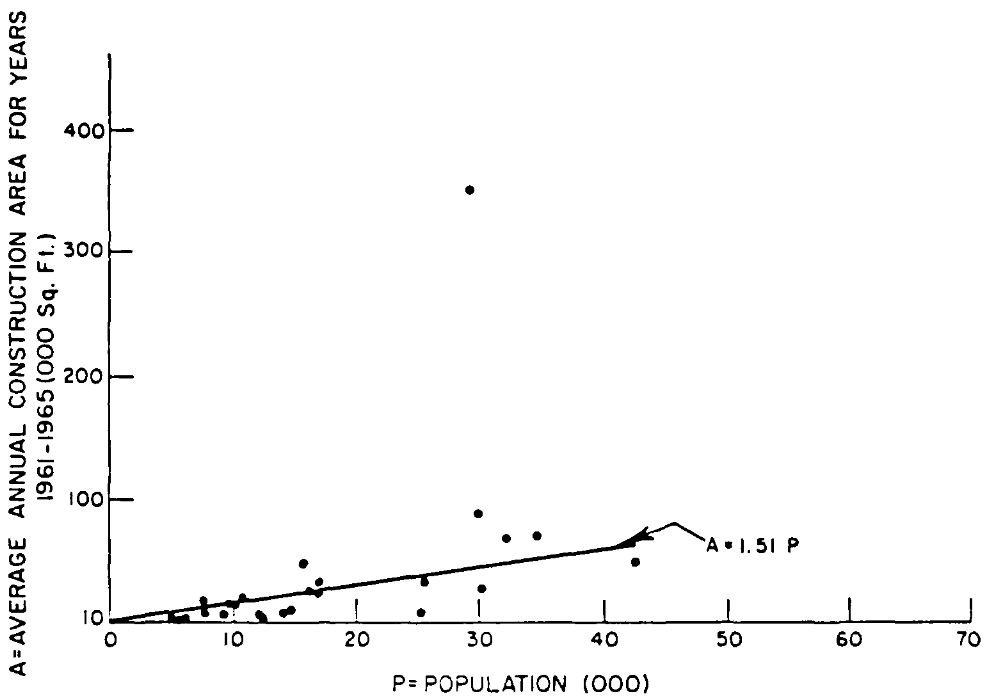
Estimating the potential shelter from this source is difficult because there is no previous survey experience for such buildings. From construction statistics of the F. W. Dodge Corporation, it is obvious that the number of such structures is very large, as illustrated by Figures V-9 through V-12. These figures developed by RTI in a 1973 study for FEMA [6] are based on Dodge construction statistics for the years 1961 through 1965.

The significant differences between Figures V-9 and V-10 suggest that population growth has a strong effect on new construction areas. Figures V-11



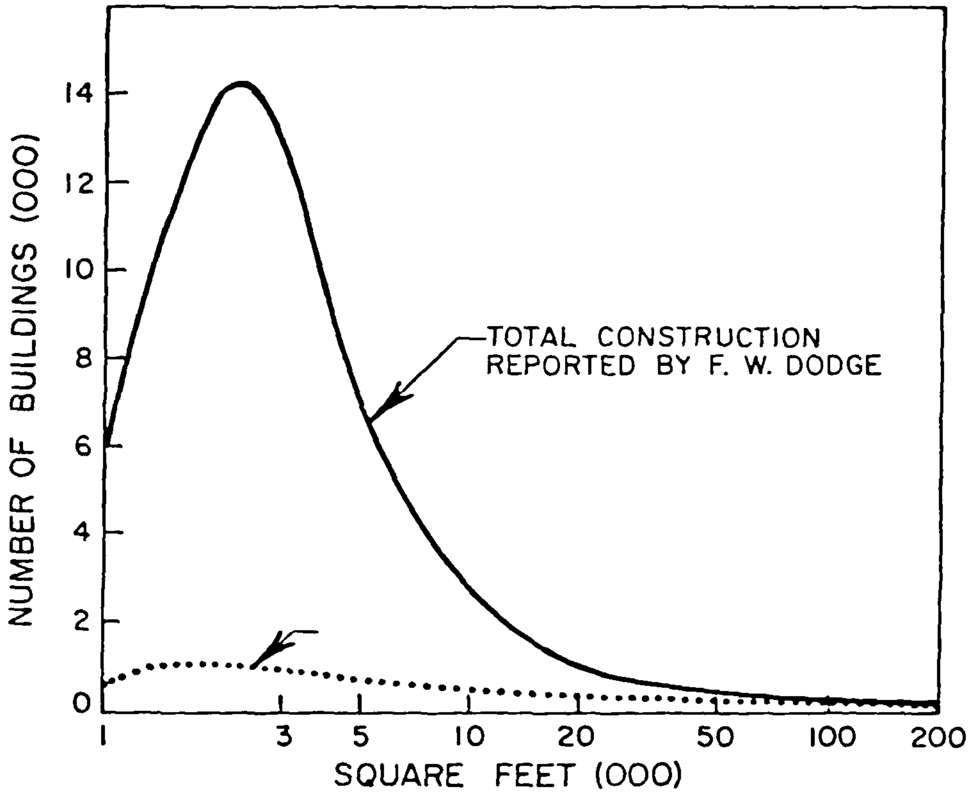
Source: Reference 6

Figure V-9. Relationship of Population and Average Annual Construction for Virginia Counties with Increasing Population



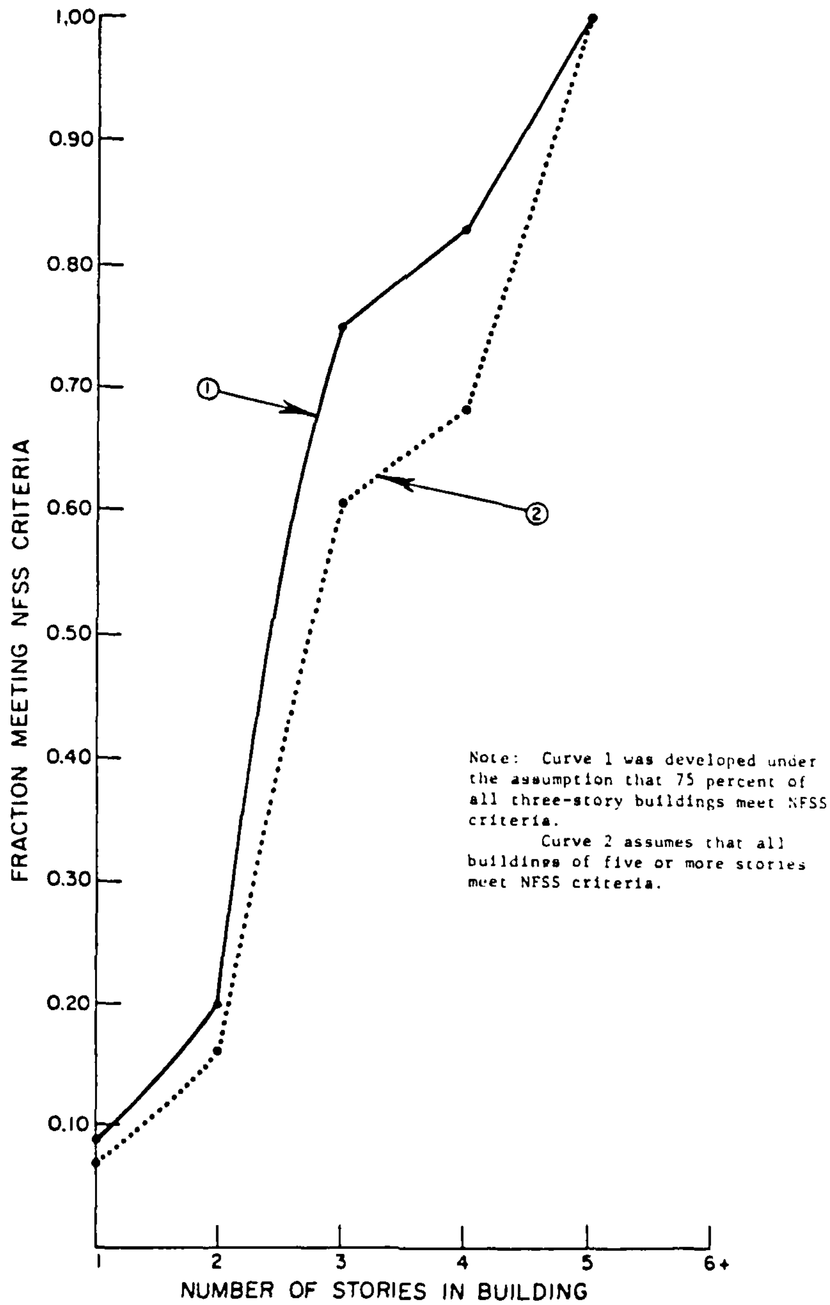
Source: Reference 6

Figure V-10. Relationship of Population and Average Annual Construction for Virginia Counties with Decreasing Population



Source: Reference 6

Figure V-11. Relationship of NSS Buildings to Total Construction (1961-1965)



Source: Reference 6

Figure V-12. Fraction of Buildings That Meet NSS Criteria

and V-12 show the effect of NSS criteria and number of stories on categorizing this area for space estimation purposes.

Two alternatives for estimating shelter in these buildings were investigated [6]. The first alternative was based on the 1961 to 1965 Dodge construction statistics, which were projected to future years based on construction value, including a factor to account for increasing costs of construction. This technique proved to be unsatisfactory for many rural counties because of the very low volume of construction projects listed in the counties during the five-year period. This low construction volume may be the general rule in rural counties and, if so, the attractiveness of this procedure is low.

A second alternative was an attempt to relate construction volume to county population using the 1961 through 1965 Dodge construction reports in conjunction with population data from U.S. Bureau of the Census reports. This procedure is defined in Section VII.

An estimate of the number of buildings in a county in new construction which qualify for the NSS may be developed from the estimate of shelter to result from an update of NSS. The spaces contained in these buildings may be estimated from the factors in Table V-8. The fraction of buildings in a specific area which do not qualify for the NSS are not contained in these factors but may be estimated using the factors in Table V-9. As would be expected, these factors are designed to yield somewhat less spaces, all on the lower floors and in the lower PF categories, than those in Table V-8 for NSS buildings.

TABLE V-8. FACTORS USED TO ESTIMATE SHELTER SPACE BY STORY AREA IN BUILDINGS THAT MEET NSS CRITERIA

	PF Category 0	PF Category 1	PF Category 2 and 3	PF Category 4 and 8	Total
<u>1 Story</u>					
Basement (V)*	0.001	0.004	0.007	0.005	0.017
Basement (A)**	0.003	0.019	0.032	0.024	0.078
Story 1	0.015	0.004	0.001	0.000	0.020
<u>2 Story</u>					
Basement (V)	0.000	0.002	0.005	0.009	0.016
Basement (A)	0.002	0.012	0.024	0.042	0.080
Story 1	0.026	0.021	0.010	0.002	0.059
Story 2	0.020	0.004	0.001	0.000	0.025
<u>3 Story and Up</u>					
Basement (V)	0.000	0.000	0.004	0.013	0.017
Basement (A)	0.001	0.002	0.021	0.056	0.080
Story 1	0.022	0.023	0.019	0.011	0.075
Story 2	0.024	0.021	0.017	0.005	0.067
Story 3	0.020	0.009	0.004	0.001	0.034

* V = Volume Basis
** A = Area Basis

TABLE V-9. FACTORS USED TO ESTIMATE SHELTER SPACE BY STORY AREA IN BUILDINGS THAT DO NOT MEET NSS CRITERIA

	PF Category 0	PF Category 1
<u>1-Story</u>		
Basement (V)*	0.014	0
Basement (A)**	0.070	0
Story 1	0	0
<u>2-Story</u>		
Basement (V)	0.015	0
Basement (A)	0.75	0
Story 1	0	0
Story 2	0	0
<u>3-Story</u>		
Basement (V)	0.012	0.004
Basement (A)	0.050	0.020
Story 1	0.060	0
Story 2	0.050	0
Story 3	0	0

* V = Volume Basis
** A = Area Basis

E. Blast Shelter

In the Development of All-Effects Shelter Survey System [7] RTI studied characteristics of the NSS data base through detailed analysis of building construction/shelter data from a survey of a national sample of NSS facilities. In conducting this analysis, visits were made to these facilities and building plans were obtained when available. Records were made of construction characteristics (frame, wall, floor) as well as in-place and upgradeable shelter space. These facilities were selected for use in developing an operational all-effects shelter survey procedure used by FEMA (DCPA). The original analysis included 250 buildings. The results of this study classified the NSS structures by a variety of construction characteristics determining blast protection ability.

Through examination of samples of records drawn from the NSS, RTI determined the frequency of occurrence of blast codes on the records of the file. Further analysis of samples of records containing blast codes enabled RTI to establish correlation between blast codes and other structural codes (such as Physical Vulnerability (PV), Special Facility (SP), and Protection Factor (PF)) in order to assign the most likely blast codes to facilities not surveyed for blast protection.

The results of the preliminary sampling are shown in Table V-10, giving totals of NSS/CRP facilities by region, as well as totals with blast spaces assigned and totals with blast codes. It was observed that the assignment of blast codes does not always correspond to assignment of blast spaces--many records assigned blast codes have no recorded blast spaces and, conversely, many records without blast codes have blast spaces recorded.

TABLE V-10. BLAST FACILITIES BY REGION

Region	Total NSS/CRP Facilities	Total Blast Facilities: Non-Zero Blast Spaces	Total Blast Facilities: Valid Blast Codes	Percent Facilities With Blast Codes
1	70,598	7,196	7,731	11.0%
2	171,448	6,865	7,426	4.3%
3	133,860	13,681	14,983	11.2%
4	184,475	10,795	12,546	6.8%
5	249,123	27,499	29,630	11.9%
6	164,307	4,990	6,500	4.0%
7	58,881	6,293	6,669	11.3%
8	43,914	5,724	6,123	13.9%
9	92,749	11,871	13,883	15.0%
10	30,998	3,797	4,338	14.0%
Total	1,200,353	98,711	109,829	9.1%

A random sample of records with blast codes was selected from all 10 FEMA regions in the NSS file. A sampling interval of approximately 90 records was used for selecting records with blast codes (that is, every 90th record in the NSS having valid blast codes was selected to be in the sample), giving a total sample of 1,165 facilities. These sampled records were then examined to determine if any correlation could be found between blast codes and other structural codes on the file.

Listings of blast codes and spaces and other structural codes were generated for all the sample records. Figure V-13 shows a partial listing for Region 4, sorted by blast code. The following is a description of the data found in Figure V-13:

- Column 1: Record number (sorted on blast code)
- Column 2: FIPS code
- Column 3: Update date
- Column 4: Blast codes for basement, first floor, and second floor and above
- Column 5: Basement code
- Column 6: Stories in building
- Column 7: PV code
- Column 8: Land use class
- Column 9: SF code
- Columns 10-12: Highest category of PF spaces found on record for basements, first floor, second floor and above (if no PF spaces were found, -1 is entered in table)
- Columns 13-15: Number of blast spaces recorded in basement, first floor, second floor and above
- Columns 16-18: Number of spaces of PF Category 0 or higher recorded basement, first floor, second floor and above

SAMPLE BLAST RECORDS
REGION 4

RECORD	FIPS	UPDATE	BLST	BS CD	STOR	PV	LUC	SF	HIGHEST PF-CAT 0	HIGHEST PF-CAT 1	HIGHEST PF-CAT 2+	—BLAST SPACES— 0	—BLAST SPACES— 1	—BLAST SPACES— 2+	—PF6+ SPACES— 0	—PF6+ SPACES— 1	—PF6+ SPACES— 2+
1.	04370190200000	7905	A00	1	0	71	32	8	3	-1	-1	29			29		
2.	04370510400972	7801	CEE	1	3	57	12	0	3	2	2	677	1050	1050	677	694	1368
3.	04370510400972	7801	CEE	1	3	57	12	0	3	1	1	258	1320	1767	258	606	1568
4	04371190050000	7905	CEE	1	12	38	11	0	2	0	2	668	960	1920	525	460	10060
5.	04370670100750	8004	CEE	1	9	43	12	0	3	0	1	20	95	492	20	95	492
6.	04280490050615	7911	CEI	1	2	43	57	0	3	2	0	20			20	690	530
7.	04121030200375	7609	CEI	1	7	57	41	0	2	2	2	1071	1714	2967	250	660	1690
8.	04130210201725	7905	CEX	1	0	35	57	0	0	-1	-1	900	900	900	110		
9.	04130570101117	7506	CEX	1	3	57	12	0	2	2	2	50	410	230	10	225	795
10.	04130510252540	7311	CEX	1	0	35	51	0	0	-1	-1	75	75	75	155		
11.	04280490050615	7504	CEX	1	0	43	31	0	0	-1	-1	20	60	30	15		
12.	04132150050660	7506	CEX	1	0	57	23	0	2	-1	-1	90			90		
13.	04132150050660	7506	CEX	1	0	57	55	0	3	0	0	515	590	590	130	260	330
14.	04371190050000	7905	CEX	1	2	35	31	0	2	2	0	45	673	92	45	235	76
15	04450450150565	7403	CEX	1	1	61	23	0	2	-1	-1	551	764	64	268		
16.	04010570250000	7502	CEX	1	0	32	46	0	3	2	-1	240	1870		80	1050	
17.	04010730150185	7504	CEX	1	0	43	31	0	2	-1	-1	45			45		
18.	04450550270000	7502	CHH	1	4	43	61	0	2	0	1	165			55	365	3802
19	04371830752020	7911	CHH	1	3	36	12	0	2	-1	-1	55			55		
20	04371830752020	7909	CHH	1	2	35	24	0	3	2	2	305			305	194	200
21.	04370670100750	8003	CHH	1	2	57	55	0	3	-1	-1	67			67		
22.	04370210150000	8005	CHH	1	3	36	41	0	3	-1	-1	62			62		
23	04211170050465	7403	CHI	1	0	36	53	0	2	-1	-1	370			30		
24	04211110351230	7504	CHI	1	0	36	54	0	2	0	0	400			400	250	250
25.	04211110351230	7504	CHI	1	3	37	53	0	2	-1	2	855			215		642

Figure V-13. Partial Listing of Sample Records From Region 4 Run

Similar listings were produced for all 10 regions describing the characteristics of the records in the blast sample.

There are anomalies to be found in the various codes and shelter capacities found on the sample records. Records are found with blast spaces assigned at a given level (e.g., second floor), but with no blast code and/or no protection factor. Conversely, a blast code is frequently assigned when no blast spaces are listed (even if fallout spaces are present). The basement code and stories entry do not always correspond to other information on the file (the stories entry is particularly suspect). Inappropriate blast codes are assigned for a given level (e.g., Codes A through D assigned for above ground levels, Codes E through I for the basement level).

However, it was found that blast spaces do correspond roughly to total spaces with PF = 0 or higher for a given floor level. (In the absence of blast spaces, the only spaces recorded on the file are those for PF Categories 0, 1, 2-3, and 4+). Further, inspection of the listings indicated that the codes most likely to be useful for predicting blast code were PV code, SF code, and highest PF level. Land use class did not appear to be correlated to blast codes.

The sample records were summarized to give total facilities by blast code and region (Table V-10) and facilities by blast code and other structural codes (Tables V-11, V-12, V-13, V-14). For each floor, facilities were grouped by blast code and PV code, SF code and highest PF level. PV codes were grouped by first digit (1x, 2x,...,9x) or as 40-59 (earthquake resistant). SF codes were identified as equal to 0, 1, 2, 3, 4, 5 or 6 and higher. Highest PF level was found for each floor as the highest PF category for which spaces were recorded.

TABLE V-11. TOTAL FACILITIES IN SAMPLE BY BLAST CODE AND REGION

Region	Basement Blast Code						Total Facilities
	A	B/C	D	E/F	G/H/I	X	
1	1	32	15		5	13	66
2		33	10	1	12	22	78
3	2	108	21	19	17	34	201
4	1	69	4	6	13	108	201
5	5	98	34	4	26	34	201
6	1	34	1	4	4	29	73
7	1	48	7		3	14	74
8	1	38	5	3	6	15	68
9	4	43	8	4	5	91	155
10	1	24	7	1	2	13	48
Total	17	528	112	42	93	373	1,165
Region	First Floor Blast Code						Total Facilities
	A	B/C	D	E/F	G/H/I	X	
1				7	46	13	66
2		3	1	26	44	4	78
3	1		7	41	146	6	201
4		1	3	57	127	13	201
5				25	129	47	201
6				19	51	3	73
7		1		9	41	23	74
8	1			14	44	9	68
9	29		2	27	78	19	155
10	1			14	22	11	48
Total	32	4	13	239	728	148	1,165
Region	Second+ Floor Blast Code						Total Facilities
	A	B/C	D	E/F	G/H/I	X	
1				3	16	47	66
2		1		13	7	57	78
3				10	26	165	201
4		1		5	30	165	201
5				2	18	181	201
6					10	63	73
7				2	12	60	74
8				7	6	55	68
9				2	24	129	155
10				1	4	43	48
Total		2		45	153	965	1,165

TABLE V-12. TOTAL FACILITIES ASSIGNED BLAST CODES VS OTHER STRUCTURAL CODES
BASEMENT - ALL REGIONS

(a) Blast Code vs PV Code

PV	Blast Code A	B/C	D	E/F	G/H/I
1X					
2X		5	36		3
3X	2	342	69	27	55
4X	1	60	4	3	11
5X		105	3	10	21
6X		4		1	1
7X	12	7			2
8X	2				
9X					
49-59		5		1	
Total Facilities	17	528	112	42	93

(b) Blast Code vs SF Code

SF	Blast Code A	B/C	D	E/F	G/H/I
0	1	521	111	41	92
1	1				
2	2	1			1
3	9	2			
4	1				
5					
6+	3	4	1	1	
Total Facilities	17	528	112	42	93

(c) Blast Code vs Highest PF Value

HI-PF	Blast Code A	B/C	D	E/F	G/H/I
No spaces	2	13	7	1	7
PF 0		72	43	8	8
PF 1		28	20		
PF 2-3	1	307	37	30	54
PF 4+	14	108	5	3	24
Total Facilities	17	528	112	42	93

TABLE V-13. TOTAL FACILITIES ASSIGNED BLAST CODE VS OTHER STRUCTURAL CODES FIRST FLOOR - ALL REGIONS

(a) Blast Code vs PV Code

PV	Blast Code A	B/C	D	E/F	G/H/I
1X					
2X				2	47
3X		4	2	70	499
4X		1	4	54	74
5X			5	91	92
6X				2	4
7X	32		1	15	4
8X					
9X				1	
49-59			1	4	8
Total Facilities	32	5	13	239	728

(b) Blast Code vs SF Code

SF	Blast Code A	B/C	D	E/F	G/H/I
0	4	5	12	222	721
1				1	
2					1
3	26				
4					
5					
6+	2		1	16	6
Total Facilities	32	5	13	239	728

(c) Blast Code vs Highest PF Value

HI-PF	Blast Code A	B/C	D	E/F	G/H/I
No spaces		1	2	73	424
PF 0	12	2	3	68	147
PF 1			2	17	31
PF 2-3	16	2	3	63	106
PF 4+	4		3	18	20
Total Facilities	32	5	13	239	728

TABLE V-14. TOTAL FACILITIES ASSIGNED BLAST CODE VS OTHER STRUCTURAL CODES
SECOND+ FLOOR - ALL REGIONS

(a) Blast Code vs PV Code

PV	Blast Code				
	A	B/C	D	E/F	G/H/I
1X					
2X				1	1
3X		2		18	77
4X				14	16
5X				12	54
6X					
7X					
8X					
9X					
49-59					5
Total Facilities		2		45	153

(b) Blast Code vs SF Code

SF	Blast Code				
	A	B/C	D	E/F	G/H/I
0		2		45	153
1					
2					
3					
4					
5					
6+					
Total Facilities		2		45	153

(c) Blast Code vs Highest PF Value

HI-PF	Blast Code				
	A	B/C	D	E/F	G/H/I
No spaces				17	42
PF 0		1		11	35
PF 1				6	10
PF 2-3		1		9	58
PF 4+				2	8
Total Facilities		2		45	153

Specifically, RTI analyzed the physical characteristics of this sample of NSS buildings, the blast codes assigned to these buildings, and the characteristics of those buildings in the NSS sample that had blast codes assigned to them and were not part of the special study. A procedure to assign a "reasonable" blast code to all facilities in the NSS was developed from this analysis.

Through examination of Tables V-12 through V-14, algorithms were developed to predict blast codes from the data on the file. Variations in the distribution of blast codes relative to the other codes were analyzed in designing the algorithms.

For basement blast codes, inspection of Table V-12 reveals that Code A facilities may be recognized as having the first digit of PV code equal 7 or higher, SF code equal 1 or higher, and PF levels of 4 or more. The non-Code-A facilities were mainly assigned Code B/C for the basement level, and the distributions of these remaining records do not seem much affected by PV code, SF code, or high PF value.

Examination of Table V-13 for first floor blast code, reveals that Code A facilities are those with first digit of PV code equal 7 (that is, earth covered structures) or SF code of 3 (tunnel). The use of Code A for above ground spaces was found to be regionally dependent; 29 of the 32 facilities with Code A assigned to the first floor were found in Region 9. The majority of the remaining first floor blast Codes were G/H/I, although facilities with first digit of PV code 5 or higher showed a greater tendency to be assigned Code E/F, as did those facilities with high PF value of 2 or higher.

From Table V-14 it was determined that blast codes assigned to the second floor or higher were predominantly G/H/I. There appeared no appreciable

variation in distribution of second floor blast codes for different PV code, SF codes, or high PF codes.

As a result of the analysis of the sample data, algorithms were developed for predicting blast code and blast spaces from other structural codes and spaces on the file. These algorithms are presented in Section VII.B.2.b, together with a comparison of the spaces per blast code predicted by these algorithms to the actual spaces found in our sample.

VI. METHODOLOGY

A. Allocation Problem Definition

This section discusses the Grid File (GF) input to TENOS that describes the initial state of the population and shelter in the geographical area of simulation. It is one of three primary inputs to the evaluation of the given Crisis Relocation Plan (CRP) under a given attack scenario.

The detail, extent, and reliability of the shelter space data input to the GF have been discussed previously in Section V.A. What remains to be presented is the reconstruction of the GF. The methodological basis for a Grid File Construction Algorithm is presented in this section of the report.

1. Basic Problem

The program which developed the GF could not be found. Thus, although the origin of the existing GF is not well known to the RTI staff members several features of its input and construction can be inferred. The existing GF exhibited two major defects discussed in the following subsections which need correction.

The first defect is defined as inaccessible shelter spaces. That is, shelter spaces in grids without population or where the number of spaces in a cell is too large for the population assigned to it; in the latter case, such spaces are not accessible to people in other grid cells who have need for them because of the manner in which TENOS matches people to shelter. The second defect arises from a statistical aspect of the relationship between the shelter space centroid distribution and the attack blast effects distribution.

a. Inaccessibility

The first defect results in an over-estimation of casualties because a significant number of the shelter spaces cannot be used by TENOS when estimating their value to protect people. Although the GF may report a shelter in a particular grid cell, the shelter can be filled only in proportion to the population reported as resident in that same grid cell. If that population is zero or too small together with its hosted population, TENOS will ignore some shelter capacity. Such shelter spaces are inaccessible: i.e., spaces are there but TENOS cannot move people into them.

The inferred construction of the existing GF produces these undesirable errors in two distinct ways: the Standard Location Area (SLA) codes describing the shelter locations have remained identical in definition and format to those of the 1960 census; the corresponding codes for population have been modified in response to demographic changes in subsequent censuses. This discrepency can produce detailed differences between locations of shelters and locations of population served by those shelters.

The second way that a shelter becomes inaccessible, even if the SLA codes for population and for shelter coincided, arises from local differences between the concentration of shelters and the concentration of population. TENOS billets people into a cell in proportion to the resident population reported for that cell. The constant of proportionality is called the Hosting Factor (HF) and is prescribed by the CRP input to TENOS. The hosting factor for a cell is not, however, unique to it but derives from a ratio of county-averaged population and shelter concentrations. There are typically 1500 cells in a county (though many are blank and therefore absent from the GF) and at this level the two variables deviate significantly from their

average values. The use of county average hosting factors tacitly assumes that any person can use any shelter in his county, but in fact TENOS allows him access only to shelter in his cell. So excess shelter in one cell is inaccessible to excess population in the neighboring cells.

This inconsistency clearly under-utilizes shelter and, more importantly, over-estimates casualties among those unsheltered populations. The use of hosting factors that move people to people rather than directly to shelter apparently arose historically from sound judgements on the relative reliability of the population and shelter location data. In any case, it is firmly established in TENOS and is not open for alteration. Similarly, cell specific hosting factors are probably too detailed to be intuitive and would certainly entail a voluminous CRP (maybe 1500 times as voluminous for local CRP's). Therefore, the county-average hosting factors are also not negotiable.

b. Statistical Reliability and Resolution

The second major defect in the current GF could lower the reliability of TENOS enough to invalidate any single run for a small region dominated by counties at partial risk. Only blast effects are in question here and only in certain regions. TENOS simulates casualties consequent to a blast on a discrete demography of separated population centroids. The radius of effect for blasts is sharp enough that damage at a single given point (like a centroid) usually is either total or negligible. When the separation between population centroids exceeds twice the radius of effect, the estimation of the effect of a single blast becomes statistically unreliable: one might produce no effect while an identical blast nearby could completely decimate an entire enumeration district. If many more blasts occur in such a

zone, the statistics will eventually average out for that zone but even then 10 percent damage will mean that 10 percent of the districts are destroyed and 90 percent are untouched.

The problem here is the resolution or size of the enumeration districts or blockgroups in the grid file. Resolution limits the minimum size of an effect that can be resolved by TENOS. Smaller weapons are only statistically meaningful because a single such weapon either falls on a centroid or between centroids (with the correct probabilities that will of course emerge if the blasts are numerous enough). Still smaller weapons or larger districts require correspondingly more weapons to produce stable averages.

The underlying concept here is the shortest distances over which important effects change, or more conveniently, the size of the smallest area over which important effects are constant. The two candidate effects are blast and fallout. Fallout effects vary at a slower rate geographically than blast effects. Therefore, the blast zone of the smallest important weapon is clearly the limiting size in the problem. This is assumed to be the limiting size designed into TENOS: the size of one cell in the 2' cartography of the grid file. One cell is about 2.4 km on a side yielding a 5 or 6 km^2 minimum blast area.

The weapon size must be measured against the size of the area represented by a population centroid: the size of enumeration districts in rural areas, and the size of blockgroups in urban areas. This typical area varies widely from perhaps half a cell in a city central business district to several hundred cells in remote desert or mountainous regions. The range, however, falls neatly into three categories for purposes of TENOS reliability. First, in <u>risk</u> zones population areas are of the order of a cell size permitting

reliable treatment of even the smallest weapons. Second, nonrisk zones include untargeted cities and sparsely populated areas where centroids may represent enormous areas where reliability would be suspect if the zone suffered a blast. However, the problem is academic since nonrisk means no blasts and even coarse resolution is adequate for fallout. So here too the reliability is adequate if only in a trivial sense. Third, are near-risk zones where current practice fails. Near-risk is used here to mean a middle ground between the high risk zones described in CRP plans and the nonrisk zone described above. The district sizes range from a few cells to perhaps ten cells thereby exceeding the weapon size and permitting excessive statistical variation. Moreover, these near-risk zones are in some danger of blast because they may likely be struck by weapons that miss intended target; they may host enough population to therby become attractive targets themselves; or they may contain military and manufacturing targets located on the periphery of the neighboring risk zone.

Therefore, passive dependence of grid file resolution on demographic reporting format is inadequate in near-risk zones. However, since TENOS treats cells independently and sequentially, no simple modification of TENOS itself is possible. Therefore, TENOS itself cannot refine the resolution of the GF input.

Improving the GF resolution in near-risk zones will entail substitution of several grid file records for certain single centroid records in the file. While this increased resolution improves reliability by permitting partial destruction of an enumeration district, it does so at the cost of longer TENOS run time. On the other hand, the district-size resolution in nonrisk zones is often finer than required. TENOS run time could be decreased by somehow

consolidating such grid file records to represent groups rather than single districts. If a coarser resolution is adequate for the effects suffered (fallout or even no effects), reliability will not be jeopardized.

2. Qualifications and Assumptions

The most rigid constraint on possible improvement of the grid file construction is that TENOS code is inviolate. Nevertheless, there are several desirable features of an improved construction. For example, construction that reduces eventual TENOS runtime is attractive because, within the bounds of reliability, the faster TENOS can process a grid file, the better. In addition, the inconvenience of many diverse additional input requirements detracts from a candidate construction. County boundary data or even census boundaries are available but bulky and would require maintenance and library effort. Finally, the concepts embodied by the current grid file should be preserved where possible. Gross violations that would exploit TENOS idiosyncracies even to the benefit of results must be avoided. One such case involves the improper assignment of a cell just within the boundary of one county to both counties. Boundaries cannot be preserved by refinement of resolution if boundary data is not provided. But examination of the current grid file reveals that a single cell (same latitude and longitude) is often reported within two different districts. Repeated grid records may be undesirable but TENOS at least can handle them.

The development of the grid file allocation algorithm must incorporate several general objectives as well as improvements in accessibility and reliability examined above. Those objectives include processing shelter survey data and census data in reasonable time and memory requirements with accurate, TENOS-readable output. A variety of component algorithms were

identified, assembled into system algorithms, evaluated in concert, modified, and reconsidered. Where clear choices existed alternative ideas were rejected, but utimately TENOS will provide the criterion of merit. Because the details of TENOS functions and applications are not available, optional alternatives within the algorithm provide the user with a means for determining best practice experimentally.

B. Alternative Methodologies

1. Introduction

Before developing the grid file algorithm, it is appropriate to describe at least several known procedures for the allocation of values to geographic locations which represent a more realistic spread of these values than originally described. The first deals with the distribution of emission sources (usually buildings) where data is available normally only at the county level. The second deals with the distribution of population to a uniform grid system where the original population estimates were known only at the enumeration district or blockgroup level. The third encompasses a family of very general techniques for refining a collection of values by the use of some overall feature of the collection.

2. CAASE

The Computer Assisted Area Source Emissions (CAASE) system [4] was developed to calculate emissions across a given study region for area sources, i.e., those ubiquitous, individually small sources which cannot be specifically located. A central part of this system is a gridding method that seeks to improve the characterization of area sources. Basic data for determining area source pollutant emissions, computed by the application of appropriate emission factors, are rarely available for geographic or political

units or areas smaller than the county. The geographic size of a county, however, is too large for practical use in simulation models for Air Quality Control Regions (AQCR's) or Air Quality Maintenance Areas (AQMA's). Thus, the CAASE objective (automatic) computer gridding of the study area is used to produce suitable inputs for several such simulation models. The method also includes the assignment of population and housing counts to grid squares in proportion to the area of the grid square within each county, although only population will be considered for the remainder of this discussion.

The major steps that lead to the construction of the CAASE grid square system are (1) the definition of the study area in terms of numerical county outline data, (2) the creation of a proximal map and a population density surface, and (3) the gridding procedure. Ignoring the details of step (1), and assuming a defined study area of 1 km by 1 km unit cells, the construction of the proximal map and the population density surface takes place as follows. Each unit cell has an assigned value of 1 km^2 if it is interior to the boundary of a given county within the study area, 0 km^2 if it is exterior to the boundary, and a value between 0 and 1 km if it is on, or transected by, the boundary. Essentially, the proportioning of unit cells is the operative definition of the study area. Also, associated with each cell are the census enumeration districts (ED's) whose centroid coordinates fall within that cell. There may be none, one, or more such ED's for a cell. Unit cells with one or more ED's assigned to them are called control cells analagous to the cartographer's phraseology of control points (data) in topographic map construction. The proximal map is constructed by assigning to each non-control cell the value of the control cell nearest it. A random number decides ties. Thus, for each control cell there is a collection of non-

control cells, namely those closer to it than to other control cells. Collectively, these cells approximate the original census tract (at least down to the resolution afforded by 1 km by 1 km grid cells) and can be named a pseudodistrict or pseudotract. The cell areas are summed to obtain the total ED area. The ED population divided by this area is the population density, i.e., the population per square kilometer, throughout the collection of cells. Since all the cell sizes are 1 km^2, the value of population density assigned to each cell is simply the population in that cell. Populations for unit cells on the county boundaries are adjusted proportionate to the area values found earlier; thus, population density remains uniform across counties for a given unit cell.

The above process is applied to every control cell. Eventually, the entire study area has values of population assigned to all unit cells. This set of values is the population density surface.

The gridding procedure attempts to overlay grid squares on the proximal map so that each square contains approximately the same population. This aggregation of cells into layer squares effectively reduces the resolution of that region by substituting a single square-centroid for the cell-centroids contained in that square. The population of any grid square is, of course, the sum of the populations of the unit cells in that square. Somewhere there is at least one unit cell of maximum population, and this unit cell will be the smallest grid square. This maximum value of population is approximately the population which all other squares are to contain in the partitioning. Thus, the grid system with the study area centered within it is initially a set of squares of equal size that are probably "too large." "Too large" a square means that the total population in the square exceeds the maximum

population previously mentioned. The square is then partitioned into 4 smaller squares (daughters) by dividing its side length by 2. The daughters are added to the list of squares in the system. The daughters are then tested for being "too large." Any time the "too large" condition occurs, the square is partitioned down to the next smallest size, until the partitioning reaches the unit cell size, if necessary. If the "too large" condition does not occur, inspection passes to the next square in the list. If there are no more squares in the list, the procedure is completed.

3. PLUM

The gridding procedure for the North Carolina Planning and Land Use Management Information System [5], hereafter called the PLUM system, grew out of initial development work to obtain population estimates for PLUM. Since the grid cells used for these estimates were of arbitrary, equal size, this gridding procedure is actually a population allocation model. Briefly, the PLUM system is a land use information system that provides a variety of information on natural and man-made environmental characteristics as well as important demographic characteristics.

Since household allocation models already existed, household estimates were to be obtained by such a model and then converted to population estimates by multiplying the estimated number of households by the average number of persons occupying a household. Therefore, the first step in developing a population allocation model was to select a household allocation model.

One difficulty with choosing a household allocation model for PLUM was that the available models had been developed for urban settings, since land use planning is desperately needed in many urban areas and data are more readily available in such areas. However, the PLUM scenario is an all

encompassing one requiring household estimates to be made in both urban and rural areas. Also, data requirements had to be minimal because data did not exist for estimating the model parameters in many of the models cited in the literature. This was found to be true for rural regions as well as many urban regions.

Among the household allocation models considered, the gravity models were chosen as the most appropriate basis for the PLUM allocation model. Gravity models for household allocation developed from the traffic assignment models of transportation planners. They found that the gravity-type model introduced by Reilly in 1929 to describe the interurban movement of tripmakers could be used to approximate intraurban travel as well. Although principally devoid of behavioral considerations, this methodological advance became the basis of land use growth models. The approach is based directly on the empirical observation that the type and use at a location is recriprocally related to the type and intensity of travel behavior at that location. Thus, as the city grows, the pattern of land use is modified, and, the more accessible a location becomes in relation to all other locations, the more likely it will be more intensively used. Stewart's commonly accepted method for describing the orientation of an individual in space renders an index of accessibility for any location. This index is expressed

$$A_i = \sum_{j=1}^{n} \frac{S_j}{d_{ij}{}^b} \quad , \text{ where}$$

S_j = a measure of the intensity of opportunity in an area j (employment, social, or retail trade opportunities although most household allocation procedures use employment opportunities only);

d_{ij} = the distance between area i and area j, usually expressed as minutes of travel time to take into account space - transforming technological innovations between different periods of time; and

b = an empirically determined exponent describing the effect of distance over the attenuation of trips for the particular urban area under study.

There were several reasons why gravity-type models, based on such indexes of accessibility, were considered the appropriate basis of a model for PLUM household, and thus population, allocation. The data required by this approach was minimal, consisting of household data summarized by geographical region and an estimate of the average occupancy of the households also reported by region. Also required was area data for the regions including some measure of that part of the land area that cannot be used for residential occupancy. This was obtained by subtracting the area occupied by state parks, lakes, river basins and other bodies of water from the land that is usable for supporting a permanent population.

An additional reason for utilizing the gravity model approach was that gravity models could utilize the 1970 census data effectively. The population model could more accurately distribute population if the population data existed in a highly disaggregated level of geographical detail. Therefore, the North Carolina Enumeration District (ED) and Block Group (BG) data (which disaggregates the total population of North Carolina into over 6,307 smaller population units) was used as the principal source of population data, and this population was distributed to the grid cells in the PLUM system.

The details of the model used to distribute population in the PLUM system can now be described. Let

H_i = the number of households residing in the i^{th} Enumeration District (Block Group);

P_i = the number of people living in the i^{th} ED (BG);

$M(k)$ = the index set of grid cells that have part or all of their area residing in the k^{th} county;

d_{ij} = the distance between the geographical centroid of the i^{th} ED (BG) and the j^{th} grid cell;

A_j = the usable land area of the j^{th} grid cell;

W_{ij} = the unknown number of population that is assigned to the j^{th} grid cell from the i^{th} Enumeration District;

G_j = the population of the j^{th} grid cell;

M = the index set of all grid cells;

U_i = the average number of people living in the i^{th} ED (BG) per unit of housing;

b = an empirically derived constant;

C_i = a constant of proportionality derived for the i^{th} ED (BG);

N = the index set of all ED's and BG's.

Then a model for allocating population based on Stewart's model discussed previously is described by the following three equations:

$$W_{ij} = \frac{C_i A_j}{(d_{ij})^b} , \tag{1}$$

$$\sum_{j \in M(k)} W_{ij} = H_i \times U_i = P_i \text{ for all } i \text{ and for all } k , \tag{2}$$

$$\sum_{i \in N} W_{ij} = G_j \text{ for all } j . \tag{3}$$

Equation (1) states that the number of people assigned to the j^{th} grid cell from the i^{th} ED is directly proportional to the developable land area of the j^{th} grid cell and inversely proportional to the distance between the j^{th} grid cell and the i^{th} ED (BG) raised to the power b.

Equation (2) states that the total number of people assigned to the grid cells in the k^{th} county from the i^{th} ED must equal exactly the number of people that exist in the i^{th} ED. The effect of this equation is to force the total number of people assigned to the grid cells occupying the k^{th} county to equal exactly the total number of people that live in the k^{th} county according to the 1970 Census data.

Equation (3) states that each grid cell's population equals the sum of the grid contributions from all of the ED's in the PLUM system. It should be noted that due to equation (2) the contributions to the i^{th} ED will only come from those cells that fall in the same county(s) as the i^{th} ED.

There are two sets of parameters in equation (1) that need to be estimated, C_i and b.

If equation (1) is substituted into equation (2), we get

$$\sum_{j \varepsilon M((k)} W_{ij} = \sum_{j \varepsilon M(k)} \frac{C_i A_j}{(d_{ij})^b} = P_i \text{ for all } i.$$

Therefore,

$$C_i = \frac{P_i}{\sum_{j \varepsilon M(k)} \frac{A_j}{(d_{ij})^b}} \text{ for all } i. \qquad (4)$$

Using equation (4) to estimate the constants of proportionality (C_i for all i), a direct solution for W_{ij} can be expressed as

$$W_{ij} = Pi \frac{\frac{A_j}{(d_{ij})^b}}{\sum_{j \varepsilon M(k)} \frac{A_j}{(d_{ij})^b}} \quad \text{for all } i.$$

The parameter b is obtained experimentally by a method such as the following:

a. Select a random sample of grid cells from the PLUM system.

b. Calculate the household estimates for different values of b. These are obtained by substituting the value 1 for the U_i average household occupancy in equation 2.

c. Overlay the PLUM grid system on culture maps that show household location.

d. Count the number of households falling in the randomly selected grid cells.

e. Compare estimates made in step 4 with the estimates made in step 2.

f. Select the value of b that produces the best estimates of household distribution from a least squares (minimum squared error) or some other minimum error point of view.

4. Relaxation

Relaxation implies an approach to the estimation of a collection of values by the iterative application of an interrelationship that the collection should jointly satisfy or, more simply each current value is in turn adjusted to properly relate to the other current values. This approach frequently leads to simple and efficient procedures. Relaxation techniques are therefore commonplace in numerical applications. They are used to examine non-linear differential equations as well as to smooth noisy data.

An illustrative problem would be to determine the temperature throughout the insulating jacket of a steam pipe. In cross-section the continuous T field can be described by a grid of discrete cells. Intuitively the temperature falls smoothly from a high at the inner surface against the steam pipe to a low at the outer surface of the insulation against the surrounding air. Mathematically, the T's obey a homogeneous second order linear differential equation called Laplace's equation ($\nabla^2T = 0$) with the specified

boundary conditions of the pipe and air temperatures. Under relaxation, however, the T of each cell between pipe and air is simply replaced by the average of its four nearest neighbors. This process is repeated until it does not change the T's anymore (they are relaxed). The original estimates of the T's only affect the number of iterations necessary.

Unfortunately, this simple formulation cannot be directly applied to the dispersal of population because it would not conserve the total number of people. This is because Laplace's equation does not conserve its object. It is straightforward to either modify this formulation so that it would conserve population or alternatively to find a differential equation which already conserves its object. The diffusion equation, $\nabla^2 p = -r\frac{\partial p}{\partial t}$, where r is a parameter governing the rate of diffusion, conserves p and permits the use of the physical intuition of diffusion phenomena. In this case, relaxation prescribes that each p will be increased by some fraction of the average p of its four neighbors while each contributing neighbor will be decreased by the amount of its contribution. This describes a transfer of p between cells: the total p is conserved: no p is either created or destroyed.

In addition to the simplicity of this relaxation technique, it has the advantage of endless flexibility and can be easily adapted to special requirements. For instance, calculation can be restricted to cells marked for modification. Another adaptation that will prove important is to prohibit a transfer of population if it is too small (fractional).

5. Summary

These specific approaches were considered in the development of the allocation algorithm described in the following section.

C. Grid File Algorithms

The grid file construction algorithm (GFCA) must perform the following three major functions: (1) accept input population data and shelter data, (2) allocate these data to cells in a grid file format, and (3) output the grid file to some external medium, e.g., tape. The most complicated function is allocation, which involves problems of shelter inaccessibility (in the matching component) and inappropriate demographic distribution (in the resolution component).

1. Basic Procedure

a. Matching

The problem of inaccessibility, that is the problem of a shelter allocated to a different cell from the population it serves, is a problem of matching populations with shelters.

Several algorithms were considered for the matching component of the GFCA. A satisfactory solution emerged quite naturally from the critical consideration of the possibilities. The guiding principles were (1) respect the CRP hosting factors use of the county as the unit area, (2) preserve the total shelter and population within the county, (3) permit simulation of travel within county to maximize shelter occupancy, and (4) produce the most realistic distributions possible from the data available.

For the purposes of allocation the NSS shelter data falls into four categories: (1) centroidized shelter whose exact latitude and longitude is replaced by the location of the centroid of the SLA which contains it, (2) shelter in buildings that are exactly located by the NSS, (3) home basements whose distribution has been lately generated and is available by enumeration

district or blockgroup (hereafter referred to as ED), and (4) shelters whose location is erroneously reported by the NSS.

The MEDList population data is reported by ED. The total population for each such area is positioned at the population centroid of the area. The MEDList data is considered finer and more reliable than the shelter data. In fact, it is believed that the MEDList distribution of population within a SLA is a better representation of the real shelter distribution locally than is the NSS data. For the total shelter of an SLA and therefore for the distribution of shelter between SLA's, the NSS data stands alone.

The algorithm for matching population with shelter must provide two functions: (1) To redistribute the shelter data locally (within the SLA) to coincide with the distribution of population data, and (2) to redistribute the population within the county to simulate travel to available shelter. The redistribution of shelter data is complicated by the optional preservation of exactly located shelter, the preservation of basement data, and the screening and subsequent processing for erroneously located shelters. Optionally, after the redistribution of shelter within the SLA, the algorithm provides for the redistribution of population within the county to simulate travel to available shelter. This function maximizes the occupancy of shelter in the TENOS simulation and is faithful not only to the assumptions reflected in the CRP hosting factors but also the realistic behavior of a threatened, mobile population.* At this point, it would be useful to output these descriptive

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* Optional consideration could also be given here to the quality of available shelter: redistribution might reflect a warden's preference for filling the safest shelter spaces first.

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hosting factors for comparison with the prescribed hosting factors of the CRP.

Both functions can be performed by the same algorithm. In each case two distributions of quantities are input: for this discussion the fine data and the coarse data. The fine data has a superior distribution over the working area and is to be used to redistribute the coarse data. The collection of coarse data is summed and then deleted. This coarse sum is divided by the sum of the fine data and the resulting ratio is used to weight each fine datum in turn. Each such product is used to create a refined datum. The collection of these cloned data replaces the original collection of coarse data.

Symbolically, the collection of coarse data $\{C_j | j=1,2,...,N_C\}$ at N_C locations are deleted and replaced by the collection of refined data $\{R_i | i=1,2,...,N_F\}$ at N_F locations where each R_i is given by

$$R_i = \frac{\sum_{j=1}^{N_C} C_j}{\sum_{k=1}^{N_F} F_k} \times F_i \quad , \; i=1,2,...,N_F \quad ,$$

and where $\{F_i | i=1,2,...,N_F\}$ is the collection of fine data. Note that the sum of the Cs over the original N_C locations equals the sum of the Rs over the N_F locations: redistribution preserves the total value of its object.

This redistribution algorithm is used twice in the matching algorithm: first, to redistribute shelter spaces locally within the SLA to the superior population data locations and second, to redistribute optionally population in the county to the refined local shelter locations. Whether the second function is elected or not, the resulting data is a county wide collection of

MEDList population centroids, each now with a fair (either over the SLA or over the county) share of shelter apportioned to it. In the first function the inconsistent or obsolete NSS centroids were deleted.

In either case, the matched shelter and population for the county contains the minimum number of inaccessible shelters as is possible under the constraints elected by the user. With this problem eliminated, it is possible to attack the problem of adjusting the resolution of the grid file. If convenient, the entire input could be processed by a matching program county-by-county and output to external storage for subsequent reprocessing by a second program to adjust resolution. No doubt there are situations where one or the other architecture would excel, but for this report processing for the county will be assumed to continue without intermediate output.

b. Dispersal and Aggregation

The second major problem to be addressed in the allocation component of the grid file construction algorithm (GFCA) is resolution adjustment. The problem here is to disperse population and their shelter by adding centroids in regions where locally reliable blast damage results are required, while on the other hand to aggregate population and shelter by combining centroids to accelerate runtime in areas that will not be subjected to blast at all. It is also necessary to disperse centroids in those areas that possess a population dense enough to become alternative targets. This is a problem of dispersal of dense data or aggregation of sparse data. Several candidates for each of these objectives was examined. Although the resolution component of the allocation function of GFCA can now be considered separately from the matching component, its parts (dispersal and aggregation) are opposing processes and must be considered in concert. In fact, one of the

algorithms evaluated for matching shelter and population involved over-dispersal followed by compensatory reaggregation. The lesson learned from this approach is that the ramifications of the interaction between dispersal and aggregation must be carefully developed. Nevertheless, separate developments are presented initially.

(1) Dispersal

In near-risk zones or, more descriptively, areas which are close to areas in danger of attack, blast centroids can fall between the population centroids in the GF and cause no damage, if sufficient distance exists between them, when in fact some damage should be recorded. In these zones it is essential to define the centroids of the grid file to close the gaps if detailed treatment of these areas is to be satisfactory. This refinement is effected by dispersal of centroidized data over some fraction of grid file cells in some immediate neighborhood of the original centroid. The qualification of appropriateness for resolution emphasizes the fact that in nonrisk zones, this refinement might be detrimental to TENOS runtime without any compensating gains in accuracy of damage estimate.

There are at least two approaches to the pursuit of appropriateness that may be used to advantage in simultaneous coordination to achieve a good balance between dispersion and aggregation. One approach is to confine the dispersal to certain zones and confine aggregation to others. The opposite extreme is to disperse maximally all data then reaggregate where appropriate. These two approaches will suffice for present and are mentioned only to point out that the choice of a dispersal algorithm cannot be made independently of the elected approach to appropriateness.

Other criteria involved in the development of the dispersal algorithm are: complexity in terms of time and memory requirements, the apparent cost of implementation and maintenance, and intuitive appeal (its naturalness and simplicity). In addition, as mentioned in an earlier section, excessive additional input requirements are to be avoided.

There are then five basic concepts that will be examined for usefulness to a dispersal algorithm. Listed, in ascending order of sophistication and complexity, they are (a) scattering, (b) relaxation, (c) proximation, (d) empirical distribution, and (e) surface fitting. Each can be elaborated or otherwise adapted to suit the point of application and thereby better fit the context of the other components of the GFCA.

(a) Scattering

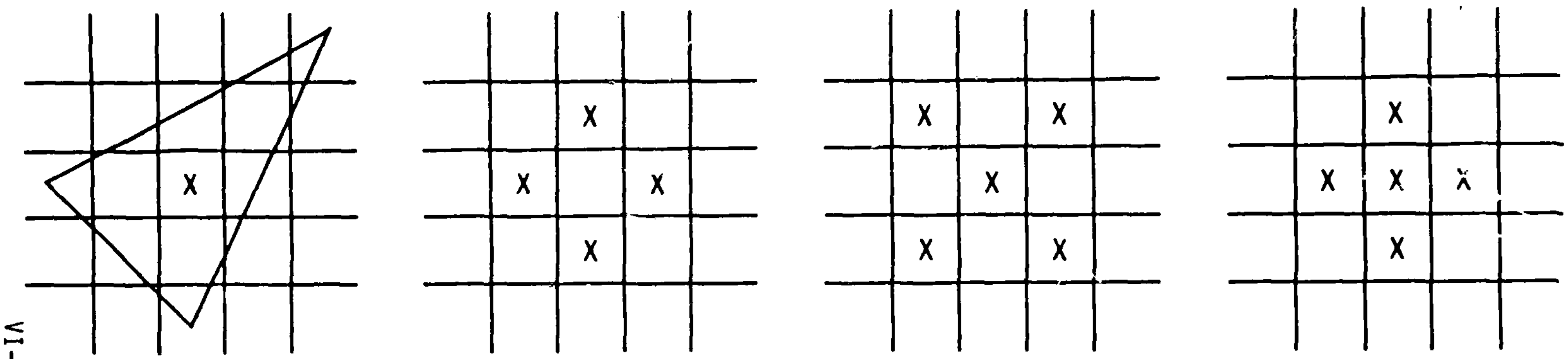
Scattering is the simplest procedure for dispersal of centroidized populations that was found to satisfy the minimal requirements of the problem. In this procedure, the local resolution implied by the density of population centroids is read from a file of ED areas or estimated from distances between the ED centroids of the SLA or neighborhood. This default resolution is compared to the required resolution. If dispersal is indicated, the centroid is replaced by a regular skip pattern of nearby cells that together approximately span the area represented by the original centroid. The skip interval is chosen to compare with the required resolution distance. The span of the pattern and the interval between cells in the pattern together determine the total number of nonzero cells in the pattern. The population at the original centroid is then divided equally among these cells. So, for example, if a population centroid represents an ED with an area of about 5 cells and resolution of 1 or 2 cells is required, the centroid cell would be

replaced by its 4 nearest neighbors as indicated in Figures VI-1a and VI-1b. For the same resolution, but a slightly larger ED of perhaps 7 or 8 cells, the original centroid would be replaced by 5 cells as in Figure VI-1c. For a shorter resolution, but the original area, Figure 1d shows the dispersed configuration. Although these very small configurations are easier to describe, the actual algorithm works for any larger ED. The algorithm is computationally simple and each centroid is treated independently from all others. Scattering is suited to refining the resolution of moderate to large sized ED's to any prescribed degree.

RTI developed scattering as a dispersal algorithm before actual plots of several counties from the existing grid file were acquired. Examination of these plots revealed an important characteristic of the data that TENOS inputs: dispersal is crucial in semirisk zones where the ED's are generally under 10 cells in area. Scattering works poorly in this range. Scattering was initially developed to deal primarily with larger areas. In addition, scattering would tend to violate SLA boundaries rather frequently by the production of overlapping cells and thus repeated grid file records. While the appeal of scattering is its simplicity, this is compromised if boundary data is required to reduce these violations. In the course of the project it was resolved to avoid additional input data, if possible. For these reasons, this earliest approach to dispersal was abandoned.

(b) Relaxation

Relaxation encompasses a variety of techniques for smoothing data. The approach is iterative and generally flexible, fast, and simple. The resulting dispersal is easily restricted to prescribed zones. Boundary data is conveniently incorporated if available, otherwise the number



a. Original Data　b. Four Nearest Neighbors　c. Fartherest Neighbors　d. Shortest Resolution

Figure VI-1. Example of Scattering

of iterations limits the span of the dispersal in a natural way. The flexibility permits modifications that reduce the number of composite cells produced.

The basic relaxation process is simply to reduce each cell population by some fraction, say half, and divide the difference equally over the 4 nearest neighbor cells, as shown in Figure VI-2a and VI-2b. Other formulations of relaxation exist but this is the simplest that conserves the total population of the entire grid, i.e., it does not destroy or create people. The process may be iterated until the desired smoothing or spreading is achieved.

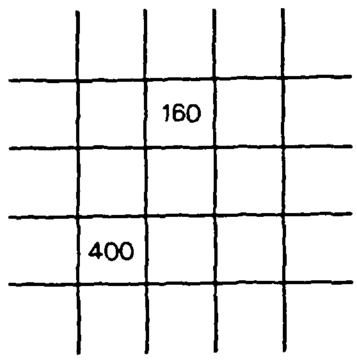
This basic formulation has several undesirable features such as diffusing population off the edge of the grid and frequently generating overlapping cells containing contributions from several population centroids (this leads to repeated cells in the GF).

Those problems, however, as well as the restriction of refinement to prescribed zones, can be treated by modification of the basic algorithm. This modification permits relaxation only into selectively labeled cells. The edges are closed off simply by omitting the label. The algorithm is completely compatible with aggregation of population centroids into SLA centroids where coarser resolution suffices.

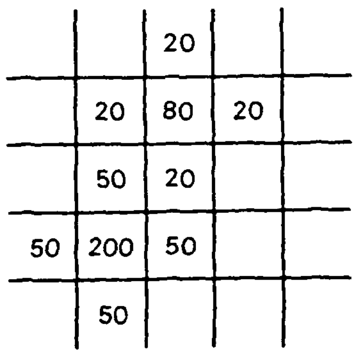
Moreover, this approach does not require boundary data. There will be, of course, some repeated cells, but means are available to reduce this effect.

(c) <u>Proximation</u>

Proximation is a third candidate for the dispersal algorithm. Proximation is used in CAASE to allocate irregular data to a finer regular grid. Proximation is slow but it produces no repeated grid file



a. Initial Distribution



b. Distribution After One Relaxation

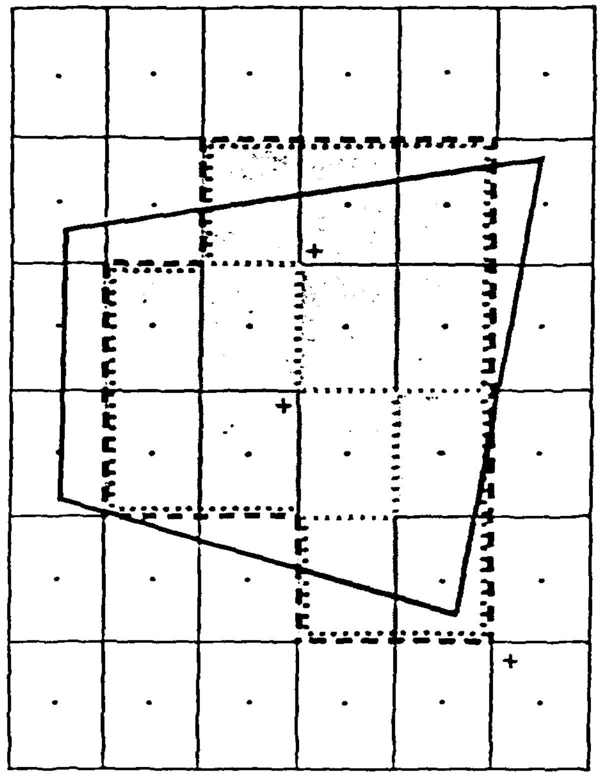
Figure VI-2. Basic Conserving Relaxation

records. The cost of this benefit is that the algorithm requires boundary data for the counties. Within the county (see Figure VI-3) a pseudodistrict is defined around each centroid as those cells that are closer to it than to any other centroid (they are proximate to that centroid). At the county boundaries this procedure fails since the centroids in other counties are not in core and cannot be used; these boundary pseudodistricts are closed off by the county outlines. The pseudodistricts deviate from the real ED's but do not overlap and lead to no repeated records. Dispersal simply divides the centroid population equally over all the cells in the pseudodistrict.

The county outline data could be replaced by county adjacency data that listed all counties that shared a border with the county being processed. In either case the additional input requirements are undesirable. Proximation therefore was abandoned as it became clear that additional input was undesirable.

(d) Empirical Distribution

The fourth candidate is the spreading of a centroidized population over the ED so as to fit an empirical distribution. This is a well known demographic technique and ordinarily the particular empirical distribution used is derived from Stewart's Index of Accessibility [5]. This method was used in PLUM to allocate population. This method also requires county outlines to cutoff the distribution function. Each cell would be completely overlapped since each contains a contribution from each centroid in the county leading to an enormous number by repeated records and require considerable processing time to sum and validate.



Legend

- Pseudodistrict
- Actual County Boundary
- Pseudocounty Boundary
- TENOS Two-Minute Grid Lines
- · Grid Center
- \+ Population Centroids

Figure VI-3. Proximation

(e) Surface Fitting

This final notion involves the fitting of a smooth surface, such as a constant term and a collection of ellipsoid normal distributions, to the centroidized data. This technique was used in ANCET [8] to parametize population data. It is more nonlocal than the empirical distribution of PLUM: the mix of centroids contributing to each cell would be completely lost. In return, the predicted population of each cell would depend on a great number of centroids and to that extent it would be a very good estimate. For purposes of TENOS, this is a very poor tradeoff since currently a centroid contributes to only one cell, the cell that contains the centroid; it is supposed that this simple correlation could be used to some extent in the analysis of TENOS output. Since some repeated records occur in the current GF, TENOS clearly tolerates some repeated records. However, the PLUM type allocation and the surface fitting both far exceed any reasonable limit of that tolerance.

Of these alternative dispersal algorithms, only the restricted relaxation method solves the problem strictly within the essential constraints. Its chief defect is the generation of some repeated records in the grid file. Proximation is the next most attractive choice (in spite of being slower) because it produces no repeated records. Although county outline data is available at Olney, use of this data is not desirable because of the additional runtime it requires.

(2) Aggregation

Aggregation provides a means of consolidating many grid file records into fewer records without jeopardizing the reliability of the ultimate TENOS output. The benefit of course is acceleration of TENOS

execution. Aggregation is appropriate in areas that are safe from blast effects, in areas subject only to fallout, and possibly in areas that were over-refined by the dispersal function of the grid file allocation component That last case is more properly called reaggregation and the principal algorithm examined derives also from CAASE where it is called gridding. In this procedure, ever larger blocks of grid cells are replaced by a single centroid cell until some resolution condition is satisfied. However, this case can be excluded from further consideration since either relaxation (or even proximation) allows dispersion to be prevented where inappropriate, obviating reaggregation. This prior prevention is simpler, more direct, and more effective than any later cure.

In the case of a nonrisk zone, however, the default resolution of the ED is often more than adequate and can be profitably reduced. Here a clear choice for the aggregation algorithm exists. It is a simple approach based on the FIPS code hierarchy. The data at the centroids of the enumeration districts (or blockgroups) comprizing an SLA or MCD are summed and the centroids deleted. The summed data is then written into the MCD centroid.

2. Summary

The grid allocation algorithm utilizes the matching algorithm followed by a restricted relaxation algorithm or aggregation algorithm where appropriate. The selected procedures are described specifically in the latter part of the next section.

VII. PROCEDURE DEVELOPMENT

A. Introduction

This section contains a concise description of the procedures developed by RTI to overcome the problems described in Section I. First, the various algorithms to overcome missing data problems and, second the selected algorithms to overcome the allocation problems are described. No effort was expended in developing appropriate file management procedures to support these algorithms.

B. Missing Data Replacement Algorithms

1. Code A - Special Facilities

a. Missing Data Replacement - Mines

While other data bases identify active mines in the country, it does not appear that information on space suitable for shelter is obtained by any other agency than FEMA. Thus, while potential candidates for a shelter survey may be identified from the lists of active mines identified by, e.g., MSHA and BM, the individual sheltering capacity of those mines can be determined only through an NSS survey.

A procedure for estimating the space potential of mines not surveyed for the NSS is suggested by the following steps:

Step 1: Check the NSS list of mines against the list of active mines maintained by MSHA. Inclusion in the NSS of the MSHA mine code would facilitate this check.

Step 2: Discount spaces in NSS mines listed as inactive by MSHA unless it can be determined that the mines are drift-entry, relatively dry, and free of noxious gases or, optionally, one decides to

use spaces in such mines in spite of the risk that the mine may be flooded, gaseous, or otherwise unusable.

Step 3: If an active mine on the MSHA/BM lists are recorded in the NSS, then use the spaces contained in the NSS and bypass the next step.

Step 4: If active mines on the MSHA/BM lists are not in the NSS, create a new shelter space record for the specific location.

(a) If exact coordinates are known, enter the coordinates else use the coordinates for the county, minor civil division or enumeration district from the MEDX file as appropriate.

(b) If a record for that location does not already exist, enter the number of potential spaces per mine for the appropriate region specified in Table VII-1. Else add the number of potential spaces to the existing record.

End of Algorithm

Note. using this procedure will permit NSS data to override automatically estimates of spaces made by use of average regional data which is less accurate.

b. Non-Mine (Code A) Facilities

Use NSS data in this category as in any other category. No effort is proposed to estimate "missing data" for this category of facility as the nature of the facility is locally quite variable both in number of facilities and in space capacity. Moreover, they are particularly susceptible to local upgrading.

TABLE VII-1. ESTIMATED SPACES AND THEIR PF CATEGORY DISTRIBUTION BY REGION

Region	Spaces In Mines	Distribution %			
		0	1	2-3	4
1	4,544	00.0	00.0	00.0	100.0
2	13,673	00.0	00.0	00.0	100.0
3	8,708	00.0	00.3	07.6	92.1
4	8,902	00.5	01.0	04.2	95.3
5	12,472	00.2	01.0	02.5	96.3
6	6,045	00.0	00.5	02.0	97.5
7	10,733	00.0	03.9	03.9	92.2
8	795	00.0	00.2	44.9	54.9
9	667	03.0	04.0	35.4	57.6
10	2,938	00.2	00.5	00.3	99.0

2. Code C, E, and G - Facilities

The algorithms for both fallout and blast space estimation described in the following subsections underestimate the total spaces by failing to consider the potential use of ventilation kits (see Section V.D.2). Insufficient data is available to devise a realistic estimation procedure at this time. Future improvements to these algorithms should reconsider this effect when adequate data has been acquired.

a. PF Categories (1-4) - Fallout Spaces

The procedure for estimating the shelter yield which would be expected in a county consists of the following steps:

Step 1: Determine the year of the last update of the NSS in the county. The implicit assumption is made that the NSS is complete through the most current update date found among the NSS facilities entered for a county. This date will not exist for nonsurveyed counties. In this case use the year 1960 as a substitute for the last update.

Step 2: Read in the number of spaces from the NSS associated with each time period in Table VII-2 through the date of last change in the NSS. (Note: see Table V-6 for specific dates).

Step 3: Calculate the new total spaces using equations in Table VII-2 including spaces reported in Step 2.

Step 4: Estimate total spaces available to date of last change in the NSS in buildings which do not meet NSS criteria. This is done by multiplying the total number of buildings for each building height by both the non-NSS multiplier and average floor area per

TABLE VII-2. ESTIMATING EQUATIONS FOR UPDATING TOTAL SPACES BY CATEGORY

Space Category (S_i)		Period (j)								
		j = 1		j = 2		j = 3		j = 4		j = 5
S_1	=	$1.86S_{41}$	+	$1.06S_{32}$	+	$1.04S_{23}$	+	$1.15S_{24}$	+	S_{15}
S_2	=	$1.62S_{41}$	+	$0.92S_{32}$	+	$0.90S_{23}$	+	S_{14}	+	S_{15}
S_3	=	$1.58S_{41}$	+	$0.90S_{32}$	+	$0.90S_{33}$	+	S_{34}	+	S_{35}
S_4	=	$0.90S_{41}$	+	$0.90S_{42}$	+	$0.90S_{43}$	+	S_{44}	+	S_{45}

where S_{ij} = space estimate in i^{th} category during j^{th} period.

and S_1 = spaces in Category 0 for all periods

S_2 = spaces in Category 1 for all periods

S_3 = spaces in Category 2-3 for all periods

S_4 = spaces in Category 4+ in all periods

story in Table VII-3 and by spaces per square foot in Table VII-4 for non-NSS buildings by story.

Step 5: Estimate total new construction floor area since date of last change using data from F.W. Dodge reports (Note: A file must be prepared from the F.W. Dodge Reports. See Appendix A for a description of this report) summing building floor areas across all projects in the county thereby giving the total construction area for each year or group of years as necessary to enable estimation for any period of interest between 1960 and the last published reports. If average building floor area is not available from these reports, then use total construction valuation divided by region average cost per square foot to estimate square footage. Linear interpolation/extrapolation or other method may be used to estimate new construction for each county since last NSS record update.)

Step 6: Use Table VII-5 to estimate the distribution of buildings by number of stories.

(a) Determine maximum number of stories.

(b) Distribute total area by height of building in stories using table factors yielding total floor area in buildings of each type.

(c) Starting with the tallest building and progressing to 1 story buildings, determine residual area by dividing the average building area in Table VII-5 (right most column) into total floor area in buildings of that height. The integer portion represents the number of buildings of that

TABLE VII-3. NSS AND NON-NSS BUILDING DISTRIBUTIONS BY REGION

Region 1 Building Size	NSS	Non-NSS	Non-NSS Multiplier	Floor Area Per Story
1 Story	.08	.92	11.5	5,200
2 Story	.17	.83	4.9	4,700
3 Story	.55	.45	.8	4,900
4 Story	.85	.15	.2	4,675
5 Story	1.00	.00	0	4,540
6 Story	1.00	.00	0	4,450
7 Story	1.00	.00	0	4,386
8 Story	1.00	.00	0	4,338
9 Story	1.00	.00	0	4,300
10+ Story	1.00	.00	0	4,300

TABLE VII-4. FACTORS BY BUILDING HEIGHT AND PF CATEGORY

	Category 1		Category 2		Category 3	Category 4
Story	NSS	Non-NSS	NSS	Non-NSS	NSS	NSS
1 Story:						
Basement	.001	.021	.006	.000	.010	.007
Story 1	.015	.000	.004	.000	.001	.000
2 Story:						
Basement	.001	.026	.004	.000	.008	.015
Story 1	.026	.000	.021	.000	.010	.002
Story 2	.020	.000	.004	.000	.001	.000
3 Story and Up:						
Basement	.001	.034	.001	.013	.014	.038
Story 1	.022	.060	.023	.000	.019	.011
Story 2	.024	.050	.021	.000	.017	.005
Story 3	.020	.000	.009	.000	.004	.001

(Spaces/square foot of construction area for each story by maximum building height)

Note: Basement factors from Reference 6 are modified to include basement distribution factors of .3 for 1 story, .35 for 2 story, and .67 for >2 stories.

TABLE VII-5. FACTORS FOR ESTIMATING DISTRIBUTION OF NEW CONSTRUCTION BY STORY*

Story	Maximum Stories in Buildings	1	2	3	4	5	6	7	8	9+	
	Area of Construction**	5,200-28,000	28,001-75,000	75,001-220,000	220,001-2,200,000	2,200,001-2,500,000	2,500,001-2,800,000	2,800,001-3,100,000	3,100,001-8,000,000	Above 8,000,000	Average Building Area**
1		1.000	0.436	0.327	0.295	0.291	0.288	0.284	0.281	0.256	5,200
2			0.564	0.423	0.382	0.377	0.372	0.368	0.363	0.331	9,400
3				0.250	0.225	0.220	0.219	0.217	0.214	0.195	14,700
4					0.098	0.097	0.096	0.094	0.093	0.085	18,700
5						0.011	0.011	0.011	0.011	0.010	22,700
6							0.014	0.013	0.013	0.012	26,700
7								0.012	0.012	0.011	30,700
8									0.012	0.011	34,700
9										0.011	38,700
10+										0.078	62,700

* Excluding one- and two-family residences.

** Square feet.

height. The residual is divided equally among all shorter buildings and added to the total square feet of each.

(d) Continue until the 1-story building residual is obtained. Ignore the last residual.

Example for Step 6: Assume that in Step 5 the estimated total construction floor area in a county is 300,000 square feet. From the top two lines in Table V-5, it is seen that the maximum number of stories expected would be four. Using the fractions under the "4" story column in Table V-5, the following initial distribution of floor area is obtained:

1-story buildings = 300,000 x .295 = 88,500 square feet

2-story buildings = 300,000 x .382 = 114,600 square feet

3-story buildings = 300,000 x .225 = 67,500 square feet

4-story buildings = 300,000 x .098 = 29,400 square feet.

The number of four-story buildings is determined by dividing the 29,400 square feet estimated for four-story buildings by 18,700 square feet, which is the average area of four-story buildings given in the rightmost column of Table 4-4.

29,400 ÷ 18,700 = 1 with 10,700 square feet left over.

The remaining 10,700 square feet is evenly distributed among the three remaining story categories which gives:

1-story buildings = 88,500 + 3,500 = 92,000

2-story buildings = 114,600 + 3,500 = 118,100

3-story buildings = 67,500 + 3,500 = 71,000.

The number of 3-story buildings is next determined by dividing 71,000 by 14,700.

71,000 ÷ 14,700 = 4 with 12,200 square feet left over.

Distributing the 12,200 square feet left over to the lower story categories gives:

1-story buildings = 92,000 + 6,100 = 98,100

2-story buildings = 118,100 + 6,100 = 124,200.

The number of two-story buildings is next determined.

124,200 ÷ 9,400 = 13 with 2,000 square feet left over.

The 2,000 square feet left over is added to the one-story buildings.

1-story buildings = 98,100 + 2,000 = 100,100.

The number of one-story buildings is now determined.

100,100 ÷ 5,200 = 19 with 1,300 square feet left over.

The 1,300 square feet left over is ignored. The final building distribution is shown below.

Number of Stories	Number of Buildings
1	19
2	13
3	4
4	1

Step 7: Multiply the number of each building size by the percentages in NSS and non-NSS in Table VII-3.

Step 8: Use the number of NSS buildings by floor area per story from Table VII-3 and multiply it by the NSS factors in Table VII-4 for each floor to obtain spaces in each category.

Step 9: Use number of non-NSS buildings by floor area per story from Table VII-3 and multiply it by both non-NSS factor in Table VII-4 for each floor to obtain spaces in each category.

Step 10: Add spaces in each category from Steps 3, 8, and 9 to obtain total fallout spaces by standard location areas.

End of Algorithm

b. Code C, E, and G - Blast Spaces

As described in Section V.E, a random sample of 1,165 records of facilities with valid blast codes was drawn from the NSS/CRP file representing all 10 regions. Summaries of this sample data were then analyzed to determine correlations between blast codes and other structural codes on the file. Based on this analysis, an algorithm was developed for predicting blast codes and spaces when none were entered on the file. The proposed algorithm was then applied to the sample records to obtain a measure of their predictive power.

Based on the analysis of the relation of blast codes to other structural codes on the file, the following algorithm is recommended for estimating blast spaces and codes for records on the NSS/CRP file. Note that code 'D' was not included as a candidate for assignment, although 125 facilities in the sample (10.7 percent) had code 'D' assigned at either the basement or first floor level.

Step 1: If any floor level (basement, first floor, second floor and above) has blast spaces already recorded, accept the space count as given. Go to Step 3.

Step 2: If blast spaces have not been assigned to any floor level, for each floor assign the total of spaces of PF category 0 and higher for that floor.

Step 3: If valid blast codes (A-I,X) are already entered on the record assign existing codes. Go to end.

Step 4: If a floor level has no blast spaces assign code 'X' to that floor. Go to end.

Step 5: For all the remaining records (those with estimated or recorded blast spaces at a given level, but no blast code already assigned), assign codes depending on floor level as follows:

(a) At the basement level:

- If first digit of PV code is 7 or greater and SF code is 1 or greater and highest PF level is 4 or greater, assign code 'A'.
- In all other cases, assign code 'C' .

(b) At the first floor level:

- If first digit of PV code is 7 or greater and SF code is 3 or greater, Assign code 'A'.
- Else, if first digit of PV code is 5 or greater or highest PF level is 1 or greater, assign code 'E'.
- Else, in all other cases, assign code 'H'.

(c) At the second floor level:

- In all cases, <u>assign code 'I'</u>.

End of Algorithm

The accuracy of this algorithm for predicting blast spaces and codes was assessed by applying them to the sample of blast records (assuming the records to have no blast code or spaces assigned) and comparing the predicted values for codes and spaces to the actual values on the records. The results are summarized in Table VII-6. It was found that, over all regions, the algorithm overestimated the number of blast spaces by 5.1 percent, and was somewhat conservative in estimating blast level. Blast spaces at levels A, B/C, D, and E/F were underestimated by a total of 14.1 percent, while those at level G/H/I were overestimated by 19.7 percent.

It is to be concluded that, although this algorithm will not produce identical codes and space counts for each record on the file, on the average, they should assign reasonable estimates for numbers of spaces per blast code (A, C, E, and G).

3. <u>Code D - Home Basement</u>

Based directly on work done by RTI under an earlier FEMA contract procedures for estimating current host area shelter availability based on existing data [6] is proposed below. These procedures include the situation of nonsurveyed counties as a special case.

The procedure for estimating the spaces available in home basements in each two-minute grid is as follows:

Step 1: If the HFPS has been performed in the county, the distribution of shelter by PF category is obtained from the files.

TABLE VII-6. PREDICTED VS ACTUAL BLAST SPACES IN SAMPLE BY BLAST CODE AND REGION

Region		Blast Code A	B/C	D	E/F	G/H/I	Total Spaces Codes A-I
1	Actual	150	14,325	7,012	9,247	31,760	62,494
	Predicted	151	19,674		7,401	33,362	60,588
2	Actual		23,333	2,386	32,542	23,160	81,421
	Predicted		14,293		12,428	26,537	53,258
3	Actual	669	42,908	14,181	88,069	78,824	224,651
	Predicted	300	50,346		29,273	110,935	190,854
4	Actual	29	35,664	2,681	66,075	103,222	207,671
	Predicted	104	30,030		44,056	118,028	192,218
5	Actual	663	48,760	10,043	28,131	58,268	145,865
	Predicted	669	53,062		29,269	77,253	160,253
6	Actual	120	24,394	15	57,675	10,571	92,775
	Predicted		12,973		44,450	59,895	117,318
7	Actual	325	29,105	2,580	11,920	25,360	69,290
	Predicted	90	22,016		47,970	69,851	139,927
8	Actual	2,470	25,937	1,610	25,740	25,224	80,981
	Predicted		26,268		13,904	8,544	48,716
9	Actual	3,784	29,932	5,601	27,501	45,715	112,533
	Predicted	2,443	22,990		32,309	90,144	147,856
10	Actual	3,100	17,309	1,120	11,960	13,026	46,514
	Predicted	120	15,701		13,559	41,637	71,017
Total	Actual	11,310	291,667	47,229	358,860	415,129	1,124,195
	Predicted	3,877	267,353		274,619	636,156	1,182,005
Total Error*		-7,433	-24,314	-47,229	-84,241	221,027	57,810
% Error**		-0.7%	-2.2%	-4.2%	-7.5%	19.7%	5.1%

* Total Error = predicted spaces-actual spaces
** % Error = total error/total actual spaces

Step 2: If NSS or HFPS data is not used, the trend in private home construction in a county is determined from the detailed census reports on housing and population for 1960, 1970, and 1980 (and others prior to 1960 if desired).

Step 3: The fraction of homes in the county which have basements is determined from 1980 census data from trends in step 2.

Step 4: The total number of homes in the county at the current time or at a future time is estimated by projecting the trend determined in step 1.

Step 5: The total number of home basements in the county at a given time is estimated by multiplying the number of homes in step 4 by the fraction of basements found in step 3.

Step 6: The number of shelter spaces in each PF category is obtained by distributing the basements estimated in step 4. The number of potential spaces is obtained by multiplying each basement by a constant which has been estimated in the literature at between 25 and 50.

End Algorithm.

This procedure may disregard a relatively large number of Code D spaces currently in the NSS. Many of these spaces are not residential but were classified as Code D because they were either brick-veneer or wood-frame buildings. Table VII-6 suggests that only about 10.7 percent of all facilities or 4.2 percent of all spaces in the NSS fall in this special class of non-residential Code D. No other evaluation was made of these spaces that would suggest whether they should be used or not. RTI suggests that the

algorithm could include these spaces without any adjustment as an option to be controlled by the user.

C. <u>Allocation Algorithm</u>

The application of the algorithm assumes that the missing data replacement algorithm has already been applied and that the only remaining problem is to effect the proper distribution of population and shelter spaces to specific grid centroids. While this algorithm describes only the procedure for distributing total spaces, it is assumed to apply equally as well to specific subsets of the blast and PF categories shown in Figure VII-1 with the possible exception of Code D residential. More will be said about this exception later.

Step 1: Assemble shelter data from "missing data" algorithms above into a file by county and SLA within county. (Note: space allocation is accomplished by county and by MCD within county.)

Step 2: Prepare core grid image for each county which defines the spatial relationship between data centroids, MCD's/ED's/BG's and the 2' x 2' grid system. (County outlines may be used to tag grids within the core rectangle as belonging or not belonging to the county although this is not necessary if some excursions across county boundaries are tolerable. Instead of outlines, the centroids for the county may be scanned for the highest and lowest latitude and longitude, checking for plausibility. Grid arrays for shelter, population, the resolution control flag, and names or codes are setup to represent all the 2' cells within

Blast Code	Fallout Codes Category 0	Category 1	Category 2-3	Category 4+	All Fallout
A					Element #3
B/C					Element #4
D					Element #5
E/F					Element #6
G/H/I					Element #7
All Blast	Element #8	Element #9	Element #10	Element #11	TOTAL SPACES

Note 1. Element #8 through #13 in Table A-9 are not used now.
Note 2. Element #12 and #13 could give distribution information on the strong wall (Codes B/C and E/F) and weak wall (Code G/H/I) structures, respectively.

Figure VII-1. Blast-Fallout Shelter Matrix

the cartographical limits found by the scan. These arrays are initialized to zero or blank as appropriate.)

Step 3: Grid NSS shelter data by SLA. Gridding is defined as the process of reassigning resources, either shelter spaces or population, which are initially located by exact MCD, ED, or BG coordinates to the grid: the lat/lon is rounded to the nearest grid array index and added to the corresponding array element.

(a) If spaces are in a facility whose coordinates are exactly known these spaces are gridded first.

(b) NSS spaces reported at the SLA centroid or missing location data are then gridded at the SLA centroid, using SLA data.

Step 4: Grid population and population related shelter spaces by ED/BG within SLA.

(a) Grid population which are normally assigned to ED's or BG's in the MEDX file.

(b) Assign (add) population related shelter (non-NSS or home basement spaces) to the ED/BG centroid. (Note: Normally the ED/BG used in the MEDX file has an MCD identification.)

Step 5: Assign a risk flag to cells. There are one or more options available when setting this flag.

(a) Option 1: If MCD is in a risk county or is a risk area within a partial risk county set, flag = 2 for all the cells within some user input distance around the MCD centroid (it is legitimate to set flag = 1 for entire county if any part of it is at risk). Go to Step 6. (Note: Partial risk counties should be subdivided into two

parts using the MEDX and risk files as a basis for this division.).

(b) Option 2: Define the MCD as a potential target if a population density after hosting is greater than some threshold value (e.g., 1,000 per cell) and set flag = 1 for all cells in county or in some neighborhood of MCD centroid as above. Go to step 6 (Note: This option requires some estimate of MCD area or county area if an average SLA area is derived from the sum of all MCD's in the county.)

(c) Option 3: If cell is known to be at risk due to a specific attack scenario (e.g., GZ and yield) showing targets outside CRP defined risk areas. Set Flag = 1. Go to Step 6.

(d) Leave flag = 0 as initialized in Step 2. (Note: This prevents relaxation.)

Step 6: If risk flag is set for the MCD, redistribute shelter from grids located in Step 3(b) to population grids located in Step 4 else go to Step 7. This redistribution procedure is called "matching" (see page VI-17 through VI-20) and is as follows:

(a) Compute a ratio between the sum of all spaces excluding exactly located shelter spaces and the sum of all populations in the MCD.

(b) Assign shelter to population grids by multiplying the population in each population grid by this ratio. (Note: This procedure preserves the total number of shelter spaces in the MCD. Care should be taken to prevent round off from

increasing or decreasing the number of spaces significantly in an MCD.

(c) Go to Step 8.

Step 7: If risk flag is not set for the MCD, aggregate all population and shelter to the MCD centroids.

Step 8: Continue Steps 3 through 7 until all MCD's in a county are gridded for both population and shelter.

Step 9: If the "matching" procedure is not elected to redistribute population among MCD's within county, go to Step 11 else--

(a) Compute the apparent hosting factor, AHF, by multiplying the hosting factor, HF, by the initial county population, PI, and dividing the result by the P_I less the population assigned to home basements. (Note: If risk Flag = 2, subtract evacuated population from P_I giving PF.)

(b) Sum all population excluding those assigned to home basements within the county, P_R, and multiply it by the apparent hosting factor, AHF, for the county to determine the public sheltered population, P_F.

(c) Compare P_F with the available spaces including exact location spaces (see Step 3a) but excluding home basement spaces as follows:

- All spaces Category 0 or greater, S_0
- All spaces Category 1 or greater, S_1
- All spaces Category 2-3 or greater, S_{2-3}
- All spaces Category 4+, S_4

(Note: If risk Flag = 2, use only blast spaces.)

(d) If $S_0 < P_F$ compute redistribution ratio by dividing the sum of the county population groups by S_0. Go to (f) below.

(e) If $S_0 > P_F$, compute redistribution ratio by dividing the sum of the county population group by S_0, S_1, S_{2-3}, or S_{4+} whichever is greater than P_F.

(f) Redistribute the population, P_R, by multiplying the shelter value in each grid [which contributed to S_0, S_1, S_{2-3}, or S_{4+} in Step 9(c) and was used in Step 9(d) or (e) above] by the ratio computed in Step 9(d) or (e) to allocate all public sheltered population, P_R, to shelter.

Step 10: If risk Flag = 1 or 2, relax sheltered population together with shelter spaces except for population in exactly known locations. (Note: An example of the relaxation procedure in BASIC code as applied to this problem is contained in Appendix B.) (Warning: The relaxation procedure does not require knowledge about MCD boundaries and may result in assigning shelter population to grids outside the county/MCD/ED/BG boundaries). Boundary control procedures are considered too complex and unwarranted, if care is taken in using the procedure. The values for relaxation rate, minimum transfer and number of iterations are used to control the dispersion. However, some excursions are likely. A rate equal to .5 with a single or double iteration and a minimum transfer of 20 people is suggested. This rate and number of iterations can be adapted to area size if this information is available or a proxy for it prepared.

Step 11: Write out grid records into the grid file from the non-zero entries of the core grid image.

Step 12: Continue steps 2 through 11 until all counties have been processed.

Step 13: Relaxation excursions create duplicate records near county boundaries. In order to increase TENOS efficiency, these duplicates may be summed to the dominant record after sorting all counties on grid coordinates.

The algorithm described above is beleieved to represent a good balance between accuracy of results and run time efficiency. The relaxation procedure can be adapted to use county boundary data if the additional complexity and run time are tolerable.

VIII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The algorithms described in Section VII reflect the best compromise between accuracy and efficiency based on our understanding of the characteristics of TENOS and the problems addressed by it. Since RTI staff members did not participate in the TENOS code development we cannot be certain about the proper relationships between the ways in which these algorithms process shelter and population data and the ways in which TENOS processes them. Nevertheless, one or more of these algorithms can be used in the development of computer code for preparing the grid oriented data required by TENOS.

At the direction of the project officer, RTI has not expended significant effort to integrate these algorithms into a system for preparing the grid file. Rather, the effort was expended in improving individual procedures or examining alternative ones.

While the algorithm for estimating Code A mine spaces is an improvement, additional effort should be expended to develop better indicators of potential shelter. The wide variance among regions suggests that geologic conditions, mining methods, and size of operations may play significant roles. Further study of such estimating parameters is needed to determine the validity of using them as a means of predicting mine shelter potential.

Other Code A shelter space estimates are considered inadequate. The potential in this category is unknown. Spaces in this category may be most valuable in risk areas rather than host areas. Host area spaces may be associated with highway culverts which are subject to flooding. Relatively

little was accomplished in this subcategory to improve estimates of "missing" data.

Blast code and space estimates using the algorithm recommended herein showed remarkably good correspondence for the sample selected. Additional samples should be taken to determine the reliability of these procedures and make any adjustment found to improve the estimation algorithm.

Methods for estimating public fallout shelter is considered to represent a significant improvement over current methods. Four areas were defined, i.e., criteria adjustments, non-NSS spaces in old construction, NSS spaces in new construction and non-NSS spaces in new construction. The procedures are automatically self-correcting when the NSS is updated since the "missing" component diminishes as the current date is approached and vanishes when information is current. More work should be expended in developing and updating input files containing data from the F.W. Dodge reports and additional work should be undertaken to estimate the impact of ventilation kits on the available shelter spaces.

The home basement estimating algorithm is believed to be adequate. Additional work should be done to estimate the protection afforded by these basements and whether the owners would be willing to share them with relatives, neighbors or evacuees and, if so, to what extent could they be utilized. The present procedure confines their use to the occupants of the homes.

In general, data collected by samples taken from the NSS raise questions about the accuracy of the data. For example, blast spaces were found without blast codes and blast codes were found without blast spaces. It is not known

whether these were spurious results of our sampling procedures or not. This matter should be investigated by a careful audit of the NSS data base.

The 2' x 2' grid system seems adequate for population and shelter location. However, the changed relationships between 1960, 1970, and 1980 census taking and shelter location by MCD deserves further study. There is a real need to develop a clearly defined correspondence file which will enable an improved shelter location procedure for the NSS that is consistent with census locations especially for 1980 census data. In addition, a boundary file for these areas should be investigated as a means for improving the relaxation procedure proposed in the shelter location algorithm.

The shelter data available from all sources is more detailed than that which is required by TENOS or admitted by the record structure of the grid file. For example, the distributions of blast spaces in each of five categories can be described at four radiation protection levels and by at least two levels (above ground and below ground) in buildings. However, the current grid file admits only eleven fields for shelter data. No specific conclusion can be reached regarding how much of this data can or should be passed on to TENOS.

B. Recommendations

RTI recommends that some or all the algorithms described in Section VII be included in a set of computer code which will enable the preparation of an improved grid file for TENOS.

It is recommended that consideration be given to further work in the following areas:

- An audit of the National Shelter Survey file;

- A study of estimation parameters for Code A spaces, especially mines;
- A project to take and evaluate additional samples of blast codes and spaces;
- A study to make more effective use of F.W. Dodge Reports in estimation procedures;
- A study of the additional potential of home basement spaces;
- The development of algorithms considering ventilation of shelter space;
- The preparation of data files needed to generate the grid file; and
- The development of code for the algorithms in this report.

Finally, after the algorithms have been implemented to support TENOS, the integrated system should be reexamined for incompatibilities and other possible areas of improvement.

IX. REFERENCES

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3. Tolman, D. F., R. O. Lyday, Jr., and G. M. Botkin. Estimated Characteristics of NFSS Inventory. Final Report 43U-717. Research Triangle Park, North Carolina: Research Triangle Institute, November 1972.

4. Haws, Richard C., and J. W. Dunn. Computer Assisted Area Source Emissions (CAASE) Gridding Procedure (Revised). Research Triangle Park, North Carolina: Research Triangle Institute, March 1978.

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APPENDIX A

SOURCE DATA

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SOURCE DATA

TABLE A-1. DCPA SHELTER CATEGORIES

Category	Shelter Category	Description	Rated MLOP/MCOP*	Rated Protection Factor (PF)
1	A	Mines and tunnels	35/25	5,000
2	B/C	Big building basements	10/7	500
3	D	Home basements	10/4	25
4	E/F	Aboveground; strong walls	8/2	55
5	G/H/I	Weak building areas	5/2	70

* MLOP = medium lethal overpressure
  MCOP = medium casualty overpressure

TABLE A-2. FIPS PLACE SIZE CODES

Code	Population Count
00	under 200
01	200 to 499
02	500 to 999
03	1,000 to 1,499
04	1,500 to 1,999
05	2,000 to 2,499
06	2,500 to 4,999
07	5,000 to 9,9999
08	10,000 to 19,999
09	20,000 to 24,999
10	25,000 to 49,999
11	50,000 to 99,999
12	100,000 to 249,999
13	250,000 to 499,999
14	500,000 to 999,999
15	1,000,000 or more

TABLE A-3. CRP RISK CODES

Code	Description	Total	Risk	Host	Neither
0	Not at risk	X		X	
1	U.A. psi only	X	X		
2	MCD psi only	X	X		
3	U.A. psi & MCD psi only	X	X		
4	MCD fallout only				X
5	U.A. psi & MCD fallout	X	X		
6	MCD psi & MCD fallout	X	X		
7	U.A. psi & MCD psi & MCD fallout	X	X		

TABLE A-4. 1970 FEDERAL STANDARD STATE CODES AND 1960 CENSUS STATE CODES

State	1970	1960	State	1970	1960
Alabama	01	63	Montana	30	81
Alaska	02	94	Nebraska	31	46
Arizona	04	86	Nevada	32	88
Arkansas	05	71	New Hampshire	33	12
California	06	93	New Jersey	34	22
Colorado	08	84	New Mexico	35	85
Connecticut	09	16	New York	36	21
Delaware	10	51	North Carolina	37	56
District of Columbia	11	53	North Dakota	38	44
Florida	12	59	Ohio	39	31
Georgia	13	58	Oklahoma	40	73
Hawaii	15	95	Oregon	41	92
Idaho	16	82	Pennsylvania	42	23
Illinois	17	33	Rhode Island	44	15
Indiana	18	32	South Carolina	45	57
Iowa	19	42	South Dakota	46	45
Kansas	20	47	Tennessee	47	62
Kentucky	21	61	Texas	48	74
Louisiana	22	72	Utah	49	87
Maine	23	11	Vermont	50	13
Maryland	24	52	Virginia	51	54
Massachusetts	25	14	Washington	53	91
Michigan	26	34	West Virginia	54	55
Minnesota	27	41	Wisconsin	55	35
Mississippi	28	64	Wyoming	56	83
Missouri	29	43			

TABLE A-5. NSS FILE LAYOUT

Item	Character Position(s)	Number Of Spaces
1. Region	1 - 2	2
2. State	3 - 4	2
3. County	5 - 7	3
4. MCD	8 - 10	3
5. Place	11 - 14	4
6. Standard Location	15 - 22	8
7. Facility Number	23 - 27	5
8. Reference Codes	28 - 39	12
9. Risk Code	40	1
10. Contain	41	1
11. Survey Office	42 - 43	2
12. Entry Number	44 - 48	5
13. SMSA	49 - 52	4
14. Military Code	53 - 56	4
15. Coordinate - Latitude	57 - 62	6
16. Coordinate - Longitude	63 - 69	7
17. Use	70 - 71	2
18. Ownership	72	1
19. Special Facility	73	1
20. Basement	74	1
21. Number of Stories	75 - 77	3
22. Power	78	1
23. EOC	79	1
24. Building Name	80 - 101	22
25. Building Number	107	6
26. Direction	109	2
27. Street Name	124	15
28. City	135	11
29. State	137	2

(Continued)

TABLE A-5. NSS FILE LAYOUT (Continued)

Item	Character Position(s)	Number Of Spaces
30. Zip Code	142	5
31. Update Status and Old Location Data	143 - 183	41
32. Year Built	184 - 187	4
33. Building Population	188 - 192	5
34. Physical Vulnerability (PV) Code	193 - 194	2
35. Fire Code	195	1
36. Air Source	196	1
37. Shelter Signs - Condition	197	1
38. Posting Data	198 - 218	21
39. Posting and Maintenance Data	219 - 231	21
40. Facility Location - Tract Do Not Use	232 - 235	4
41. Facility Location - Suffix Do Not Use	236 - 237	2
42. Facility Location - Block Do Not Use	238 - 240	3
43. Link Location - Tract Do Not Use	241 - 244	4
44. Link Location - Suffix Do Not Use	245 - 246	2
45. Map Number Do Not Use	247 - 248	2
46. From NODE Do Not Use	249 - 252	4
47. To NODE Do Not Use	253 - 256	4
48. Blast Code - Basement(s)	257	1
49. Blast Code - First Story	258	1
50. Blast Code - Story 02 and Above	259	1
51. Blast Spaces - Basement(s)	260 - 264	5
52. Blast Spaces - First Story	265 - 269	5
53. Blast Spaces - Story 02 and Above	270 - 274	5
54. Basis - Basement(s)	275	1
55. Basis - First Story	276	1
56. Basis - Story 02 and Above	277	1
57. PF Cat 0 Spaces - Basement(s)	278 - 282	5
58. PF Cat 0 Spaces - First Story	283 - 287	5

(Continued)

TABLE A-5. NSS FILE LAYOUT (Continued)

Item	Character Position(s)	Number Of Spaces
59. PF Cat 0 Spaces - Story 02 and Above	288 - 292	5
60. PF Cat 1 Spaces - Basement(s)	293 - 297	5
61. PF Cat 1 Spaces - First Story	298 - 302	5
62. PF Cat 1 Spaces - Story 02 and Above	303 - 307	5
63. PF Cat 2-3 Spaces - Basement(s)	308 - 312	5
64. PF Cat 2-3 Spaces - First Story	313 - 317	5
65. PF Cat 2-3 Spaces - Story 02 and Above	318 - 322	5
66. PF Cat 4+ Spaces - Basement(s)	323 - 327	5
67. PF Cat 4+ Spaces - First Story	328 - 332	5
68. PF Cat 4+ Spaces - Story 02 and Above	333 - 337	5
69. Nearest Cross Street	338 - 352	15
70. Basement(s) - Area (Sq. Ft.)	353 - 358	6
71. Basement(s) - % Usability	359 - 360	2
72. First Floor - Area (Sq. Ft.)	361 - 367	7
73. First Floor - % Usability	368 - 369	2
74. Second Floor & Above - Total Area (Sq. Ft.)	370 - 376	7
75. Second Floor & Above - % Usability	377 - 378	2
76. Roof Surface Area (Sq. Ft.)	379 - 385	7
77. % Building Under Long Span Roof	386 - 387	2
78. Exterior Wall Length (Ft.) - Front	388 - 391	4
79. Exterior Wall Length (Ft.) - Side	392 - 395	4
80. Wall Exposure - Side A	396 - 397	2
81. Wall Exposure - Side B	398 - 399	2
82. Wall Exposure - Side C	400 - 401	2
83. Wall Exposure - Side D	402 - 403	2
84. Best PF - Lowest Story	404	1
85. Adequate Heat	405	1

(Continued)

TABLE A-5. NSS FILE LAYOUT (Continued)

Item	Character Position(s)	Number Of Spaces
86. Medical Facilities	406	1
87. Pharmacy Facilities	407	1
88. Water Source	408	1
89. Dining Facilities - Code	409	1
90. Dining Facilities - Seats	410 - 412	3
91. Dining Facilities - Kitchen Burners	413 - 414	2
92. Commodes	416	2
93. Beds	419	3
94. Upgradability	420	1
95. Distance to Soil	421	1
96. Congregate Care Spaces	422 - 426	5
97. Upgradeable Fallout Spaces	527 - 431	5
98. Soil Reg. for Upgradable Fallout Spaces	432 - 436	5
99. Upgradeable Below Ground Spaces	437 - 441	5
100. Soil Reg. for Upgradeable Fallout Spaces	442 - 446	5
101. Special Data Processing Codes	447 - 449	3

TABLE A-6. FORMAT OF MEDList AND MED-X DATA

Item	Character Position(s)
GACI, MEDList, MED-X, MATILDA, and MATILDA Tract Extract all contain the following items:	
1. 1970 State Code	1 - 2
2. 1960 State Code	3 - 4
3. Federal Standard County	5 - 7
4. County of Tabulation Code	8 - 10
5. Central County Code	11
6. Minor Civil Division or Census County Division Code	12 - 14
7. Place Code	15 - 18
8. Place Description Code	19
9. Size of Place Code (Sometimes blank in GACI which was prepared prior to tabulation of the 1970 census population counts in some instances.)	20 - 21
10. Standard Consolidated Area Code	22
11. Standard Metropolitan Statistical Area Code	23 - 26
12. Urbanized Area Code	27 - 30
13. Tracted Area Code	31 - 34
14. Universal Area Code Prefix	35
15. Universal Area Code	36 - 40
16. State Economic Area Code	41 - 42
17. Economic Sub-Region Code	43 - 45
18. Central Business District Code (Blank in GACI)	46
19. Area Name	47 - 76

(Continued)

TABLE A-6. FORMAT OF MEDList AND MED-X DATA (Continued)

Item	Character Position(s)
20. Basic Tract Code	
21. Tract Suffix Code	81 - 82
22. Blockgroup Code (Not relevant in MATILDA or MATILDA Tract Extract)*	83
23. Enumeration District Code (Not relevant in MATILDA or MATILDA Tract Extract)*	84 - 87
24. Enumeration District Suffix Code (Not relevant in MATILDA or MATILDA Tract Extract)*	88
25. Urban/Rural Classification Code	89
26. Ward Code (ED records only)	90 - 91
27. Congressional District Code	92 - 93
28. Housing Count	94 - 100
29. Population Count	101 - 108
MEDList contain the preceding 29 items only; MED-X also contains the following items:	
30. Longitude (Expressed in degrees and decimal equivalents of minutes and seconds as follows: 3 leading zones 3 places for degrees, and 4 decimals)	109 - 118
31. Latitude (Expressed in degrees and decimal equivalents of minutes and seconds as follows: 4 leading zones 2 places for degrees, and 4 decimals)	119 - 128
Blank	129 - 132

* The geographic codes and area names carried on the MATILDA and MATILDA Tract Extract records summarized from ED's and blockgroups are as taken from the first ED or blockgroup summarized. Hence, some codes are not applicable at all to the summary records, for example, ED and blockgroup codes. Other codes may not be entirely applicable in cases where summary records are split across urban/rural, congressional district, or other boundaries for which there are codes in the files.

TABLE A-7. FORMAT OF F. W. DODGE DATA

	Item	Character Position(s)
1.	Dodge Report Number	1 - 4
2.	Type of Input (Negative adjustment, etc.)	5 - 6
3.	Month of Dodge Report	7 - 8
4.	Year of Dodge Report	9
5.	Dodge District, State & County Codes	10 - 18
6.	Standard Location Code (Numeric)	20 - 26
7.	Not Used	27 - 35
8.	Use Class (NFSS)	36 - 37
9.	Code indicating construction as being new, an addition, or an alteration	38
10.	Not Used	39 - 40
11.	Ownership Code (NFSS)	41
12.	Dodge Information on Contractor	42 - 52
13.	Number of Stories	53 - 54
14.	Not Used	55
15.	Number of Buildings in Project	56 - 60
16.	Number of Dwelling Units in Project	61 - 66
17.	Average Building Floor Area	67 - 72
18.	Total Project Valuation	73 - 79
19.	Not Used	80

TABLE A-8. MSHA DATA FILE DESCRIPTION - HEADER RECORD

Item	Character Position(s)
1. Key value is "0000001".	1 - 10
2. Identifies Coal or Metal/Nonmetal file as follows: Coal File - "COAL " M/NM File - "METAL/NONMETAL"	11 - 24
3. Year of file data	25 - 28
4. Latest update cycle	29 - 31
5. Date of last updated in numeric "YYMMDD" format	38 - 210

(Continued)

TABLE A-8. MSHA DATA FILE DESCRIPTION - DATA RECORD (Continued)

	Item	Character Position(s)
1.	MSHA Mine ID assigned to a mining operation.	1 - 7
2.	Contractor performing work at the site of the primary Mine ID operation. Blank if owner. Coal = 1 alpha - 2 numeric characters. Metal/Nonmetal numeric only.	8 - 10
3.	Code of selected major coal producing company controlling this mining operation.	11 - 12
4.	Code for MSHA Filed office exercising jurisdiction over this mining operation. First two characters = District. First three characters = Subdistrict. All four characters designate Field office.	12 - 16
5.	FIPS code for state in hwich mine is located.	17 - 18
6.	FIPS code for county within a state in which mine is located.	19 - 21
7.	Standard Industrial Code for primary commodity mined.	22 - 26
8.	Designate a general product class based on SIC code.	27
9.	Metal/Nonmetal mine type code. Based on subunit operations code and canvass code.	28 - 29
10.	Code for status of operations of mine (active to permanently closed.) Coal = Alpha A through H. Metal/Nonmetal = Numeric - 1, 2, and 3.	30
11.	Date of latest add or change of status. YYMMDD.	31 - 36
12.	Coal seam height in inches. Coal only	37 - 40
13.	MSHA Education and Training District office having jurisdiction over this mine.	41 - 42
14.	Indicator for Education and Training showing surface or underground. U = underground; S = surface.	43
15.	Metal/Nonmetal inspection travel area. 1 alpha and 2 numeric characters.	44 - 46

(Continued)

TABLE A-8. MSHA DATA FILE DESCRIPTION - DATA RECORD (Continued)

Item	Character Position(s)
17. Company owning or having primary responsibility for the operation of this mine.	48 - 77
18. Name applied to this mine by the company.	78 - 107
19. Mailing address for this minimg operation.	108 - 137
20. City to which mail is sent for this mine.	138 - 150
21. State abbreviation for mailing purposes.	151 - 152
22. Zip Code for mailing purposes.	153 - 157
23. Name of county in which mine is located.	158 - 181
The next two items represent information supplied quarterly by the mining company on Form 7000-2. They may not accurately reflect actual accidents/illnesses reported. Occurs 4 times - one for each reporting quarter.	
24. Company statement that this company had reportable injuries or illnesses during this report quarter. 1 if yes; 2 if no.	182
25. Number of reportable accidents and illnesses given on employment form.	183 - 185
26. Filler	198 - 199
27. Year address information was added to file.	200 - 201
28. Update cycle number address information was added to file.	202 - 204
29. Year of latest change to address information.	205 - 206
30. Update cycle number of latest change to addresses information.	207 - 209
31. Number of subunit operations (formerly departments for each ID. Employment trailer count.	210
32. Information obtained from Form 7000-2.	
33. Subunit operations code.	211 - 212

(Continued)

TABLE A-8. MSHA DATA FILE DESCRIPTION - DATA RECORD (Continued)

Item	Character Position(s)
34. Next four elements are repeated four times representing four clendar quarters.	
35. Number assigned to the document upon receipt in mailroom of HSAC and stamped on form.	213 - 221
36. Average number of persons working during quarter in this operations subunit. Item 1 (2).	222 - 226
37. Total employee-hours worked during the quarter in this operations subunit. Item 1 (3).	227 - 234
38. Production of clean coal (short tons) during quarter. Item 1 (4).	235 - 244

TABLE A-9. TENOS GRID FILE

Element Number	Element Description
1	Latitude (minutes and fractions of minutes)
2	Longitude (minutes and fractions of minutes)
3	Shelter spaces 1 - Code A* shelter spaces
4	Shelter spaces 2 - Code B/C shelter spaces
5	Shelter spaces 3 - Code D shelter spaces
6	Shelter spaces 4 - Code E/F shelter spaces
7	Shelter spaces 5 - Code G/H/I shelter spaces
8	Shelter spaces 6 -
9	Shelter spaces 7 -
10	Shelter spaces 8 - Not assigned nor used for
11	Shelter spaces 9 - normal case studies
12	Shelter spaces 10 -
13	Shelter spaces 11 -
14	Population (total)
15	Overpressure (psi)
16	Fallout intensity (rad) (maximum ERD)
17	FIPS** state code
18	FIPS county code
19	FIPS MCD code
20	FIPS radiation (rem)
21	FIPS place code
22	FIPS place suffix
23	FIPS place size (see Table R-C)
24	SMSA*** (urbanized) code
25	FIPS urban area code
26	Urban/Rural code
27	CRP risk code (See Table R-D)

* Shelter category code--details are shown in Table II-3.

** The codes used are those defined in FIPS PUB 8.

*** Standard Metropolitan Statistical Area Code - A four-digit numeric code assigned to SMSA's alphabetically within the U.S. An SMSA is a county or group of counties containing at least one city of 50,000 or more population, plus any adjacent counties which are metropolitan in character and economically and socially integrated with the central county or counties. In New England the unit is a town rather than a county. One or more central cities are identified for each SMSA. SMSA boundaries may cross state lines.

TABLE A-10. NSS MINES DATA

Region 1

FIPS	DAY POP	NIGHT POP	RESIDENT POP
0100000	13459036	12360804	10510250

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
7	0	0	0	7	224	31801

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
7	32025	1	1	150	0	3

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
199	0	0	0	0	0	0

Region 2

FIPS	DAY POP	NIGHT POP	RESIDENT POP
0200000	34688936	28584442	25230729

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
12	0	1	25	13	26	177697

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
13	177748	0	0	0	0	2

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
2139	0	0	0	0	0	0

Region 3

FIPS	DAY POP	NIGHT POP	RESIDENT POP
0300000	36276996	35494089	21457690

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
138	0	12	3847	124	91671	1106224

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
123	1291496	9	0	0	0	70

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
159105	0	0	0	0	0	0

(Continued)

TABLE A-10. NSS MINES DATA (Continued)

Region 4

FIPS	DAY POP	NIGHT POP	RESIDENT POP
0400000	27260420	26554204	27925673

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
190	8601	29	17490	140	70979	1594211

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
131	1555249	12	11	21891	3045	11

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
2903	0	0	0	0	0	0

Region 5

FIPS	DAY POP	NIGHT POP	RESIDENT POP
0500000	34903296	32412784	39638888

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
74	1595	4	9241	67	23273	888753

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
58	656490	4	3	4075	12000	22

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
50652	0	0	0	0	0	0

Region 6

FIPS	DAY POP	NIGHT POP	RESIDENT POP
0600000	18993270	18493869	17902278

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
56	15	2	1830	55	6629	330091

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
54	325940	1	0	0	99999	46

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
32807	0	0	0	0	0	0

(Continued)

TABLE A-10. NSS MINES DATA (Continued)

Region 7

FIPS	DAY POP	NIGHT POP	RESIDENT POP
0700000	11321803	10993311	10667291

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
59	0	6	24704	59	24547	583969

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
59	633220	21	21	1165091	0	5

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
6447	0	0	0	0	0	0

Region 8

FIPS	DAY POP	NIGHT POP	RESIDENT POP
0800000	3687527	3542856	4962367

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
465	0	6	298	463	166230	203400

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
455	364067	44	44	74782	475	201

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
41904	0	0	0	0	0	0

Region 9

FIPS	DAY POP	NIGHT POP	RESIDENT POP
090000	24450444	21427117	18028916

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
368	7441	88	9566	368	86757	141722

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
329	211730	72	70	65182	2150	74

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
12952	0	0	0	0	0	0

(Continued)

TABLE A-10. NSS MINES DATA (Continued)

Region 10

FIPS	DAY POP	NIGHT POP	RESIDENT POP
1000000	6823500	6375371	5515259

NSS FAC	PF 0 SP	PF 1 FAC	PF 1 SP	PF 2+ FAC	PF 2-3 SP	PF 4+ SP
84	480	6	1233	83	646	244346

FAC BSMT	BSMT SP	BLAST	BLST BSMT	BL BT SP	BL F1+ SP	CRP FAC
80	243274	3	2	360	2440	0

CRP SP FAC	UP BT	UP B SP	UP B SOIL	FAC UP	UP SP	UP SOIL
0	0	0	0	0	0	0

APPENDIX B

RELAXATION PROCEDURE

APPENDIX B

RELAXATION PROCEDURE

TABLE B-1. BASIC RELAXATION ALGORITHM

RELAX

```
2000 REM
2002 D=0
2010 FOR I=1 TD E0*S0
2020 D1=D0*G(I)
2030 IF D1<D2 THEN 2090
2040 FOR J=1 TO 4
2042 N=I+U(J)
2050 IF G(N)<0 THEN 2080
2060 D(N)=D(N)+D1
2070 D(I)=D(I)-D1
2080 NEXT J
2090 NEXT I
2092 G=G+D
2100 END
```

TABLE B-2. EXAMPLE OF APPLICATION OF BASIC RELAXATION ALGORITHM

```
LIS
4 PAGE
5 MOVE 0,90
6 END
8 LIST 24,99
9 END
24 REM...INITIALIZE.......6
26 RUN 100
27 END
28 REM...INPUT POP CEN....7
29 RUN 1000
30 END
32 REM...RELAX............8
33 RUN 2000
34 END
36 REM...DISPLAY..........9
37 RUN 3000
38 END
40 REM...INP HI RES ZONE.10
41 RUN 4000
42 END
100 REM                        INITIALIZE
110 RESTORE 120
120 DATA 10,5,-1,0.1,5
130 READ E0,S0,G0,D0,D2
140 DELETE G,U,D
150 DIM G(E0*S0),U(4),D(E0*S0)
160 G=G0
170 U(1)=1
180 U(2)=-E0
190 U(3)=-1
200 U(4)=E0
210 END
1000 REM                                 INPUT CENTROIDS
1010 PRINT "POP CENS: E,S,G?";
```

TABLE B-2. EXAMPLE OF APPLICATION OF
BASIC RELAXATION ALGORITHM (Continued)

```
1020 INPUT E,S,G1
1022 G(E+E0*(S-1))=G1
1030 END
2000 REM                                RELAX
2002 D=0
2010 FOR I=1 TO E0*S0
2020 D1=D0*G(I)
2030 IF D1<D2 THEN 2090
2040 FOR J=1 TO 4
2042 N=I+U(J)
2050 IF G(N)<0 THEN 2080
2060 D(N)=D(N)+D1
2070 D(I)=D(I)-D1
2080 NEXT J
2090 NEXT I
2092 G=G+D
2100 END
3000 REM                  DISPLAY
3010 FOR S=0 TO E0*(S0-1) STEP E0
3020 FOR E=1 TO E0
3030 IF G(E+S)<0 THEN 3060
3040 PRINT USING "3D,S":G(E+S)
3050 GO TO 3070
3060 PRINT "    ";
3070 NEXT E
3080 PRINT ""
3090 NEXT S
3100 END
4000 REM                   HIGH RESOLUTION ZONE
4010 PRINT "BLAST LIM: E1,E2,S1,S2?";
4020 INPUT E1,E2,S1,S2
4030 FOR S=S1 TO S2
4040 FOR E=E1 TO E2
4050 I=(S-1)*E0+E
4060 IF G(I)=>0 THEN 4080
```

TABLE B-2. EXAMPLE OF APPLICATION OF BASIC RELAXATION ALGORITHM (Continued)

```
4070 G(I)=0
4080 NEXT E
4090 NEXT S
4100 END
```

TABLE B-2. EXAMPLE OF APPLICATION OF BASIC RELAXATION ALGORITHM (Continued)

```
POP CENS: E,S,G?2 2 100
BLAST LIM: E1,E2,S1,S2?2 9 2 4
D2=1

   100  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0

    80 10  0  0  0  0  0  0
    10  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0

    66 15  1  0  0  0  0  0
    15  2  0  0  0  0  0  0
     1  0  0  0  0  0  0  0

    56 17  3  0  0  0  0  0
    17  5  0  0  0  0  0  0
     3  0  0  0  0  0  0  0

    48 18  4  0  0  0  0  0
    18  8  0  0  0  0  0  0
     4  0  0  0  0  0  0  0

    42 17  6  0  0  0  0  0
    17 12  0  0  0  0  0  0
     6  0  0  0  0  0  0  0
```

TABLE B-2. EXAMPLE OF APPLICATION OF BASIC RELAXATION ALGORITHM (Continued)

```
POP CENS: E,S,G?2 2 100
BLAST LIM: E1,E2,S1,S2?2 9 2 4
D2=2

     80 10  0  0  0  0  0  0
     10  0  0  0  0  0  0  0
      0  0  0  0  0  0  0  0

     64 18  0  0  0  0  0  0
     18  0  0  0  0  0  0  0
      0  0  0  0  0  0  0  0

     51 24  0  0  0  0  0  0
     24  0  0  0  0  0  0  0
      0  0  0  0  0  0  0  0

     46 22  2  0  0  0  0  0
     22  5  0  0  0  0  0  0
      2  0  0  0  0  0  0  0

     41 20  5  0  0  0  0  0
     20  9  0  0  0  0  0  0
      5  0  0  0  0  0  0  0

     37 18  7  0  0  0  0  0
     18 13  0  0  0  0  0  0
      7  0  0  0  0  0  0  0

D2
 2
```

TABLE B-2. EXAMPLE OF APPLICATION OF
BASIC RELAXATION ALGORITHM (Continued)

```
POP CENS: E,S,G?2 2 100
BLAST LIM: E1,E2,S1,S2?2 9 2 4

   100  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0

    80 10  0  0  0  0  0  0
    10  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0

    64 18  0  0  0  0  0  0
    18  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0

    51 24  0  0  0  0  0  0
    24  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0

    41 30  0  0  0  0  0  0
    30  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0

    41 30  0  0  0  0  0  0
    30  0  0  0  0  0  0  0
     0  0  0  0  0  0  0  0

D2
 5
```

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Hendry, R.N., R.O. Lyday, G.L. Bilbro, M.S. Ranade, K.J. Reeves, and V.L. Herold
September 1981 (UNCLASSIFIED) 165 pages

Over the last few years, FEMA (formerly DCPA) developed a computer program for analyzing scenarios about civil defense against a national nuclear attack. This model, named TENOS (*Technique for Evaluation of National Operating Systems*), can assess the expected damage under a variety of scenarios. This study was designed to collect available population and shelter data, to analyze that data, to examine appropriate methodologies for enhancement of the quality of estimates of both blast and radiation shelter spaces within grid cells, and to design specific algorithms to be used to create or improve these estimates. These shelter and population estimates are to be contained in a grid file which is used by TENOS. To achieve project objectives, RTI examined NSS and other data bases to assess the completeness of the shelter information used by the TENOS system, developed strategies to compensate for missing data required by the TENOS model, and developed both methodologies and algorithms to allocate the NSS shelter data to the 2' x 2' grid system. The algorithms described in this report reflect the best compromise between accuracy and efficiency based on RTI's understanding of the characteristics of TENOS and the problems addressed by it. Algorithms were developed in five areas; i.e., Code A mine spaces, risk area blast spaces, host area fallout spaces, home basement spaces, and a procedure to allocate spaces and population to grid centroids.

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